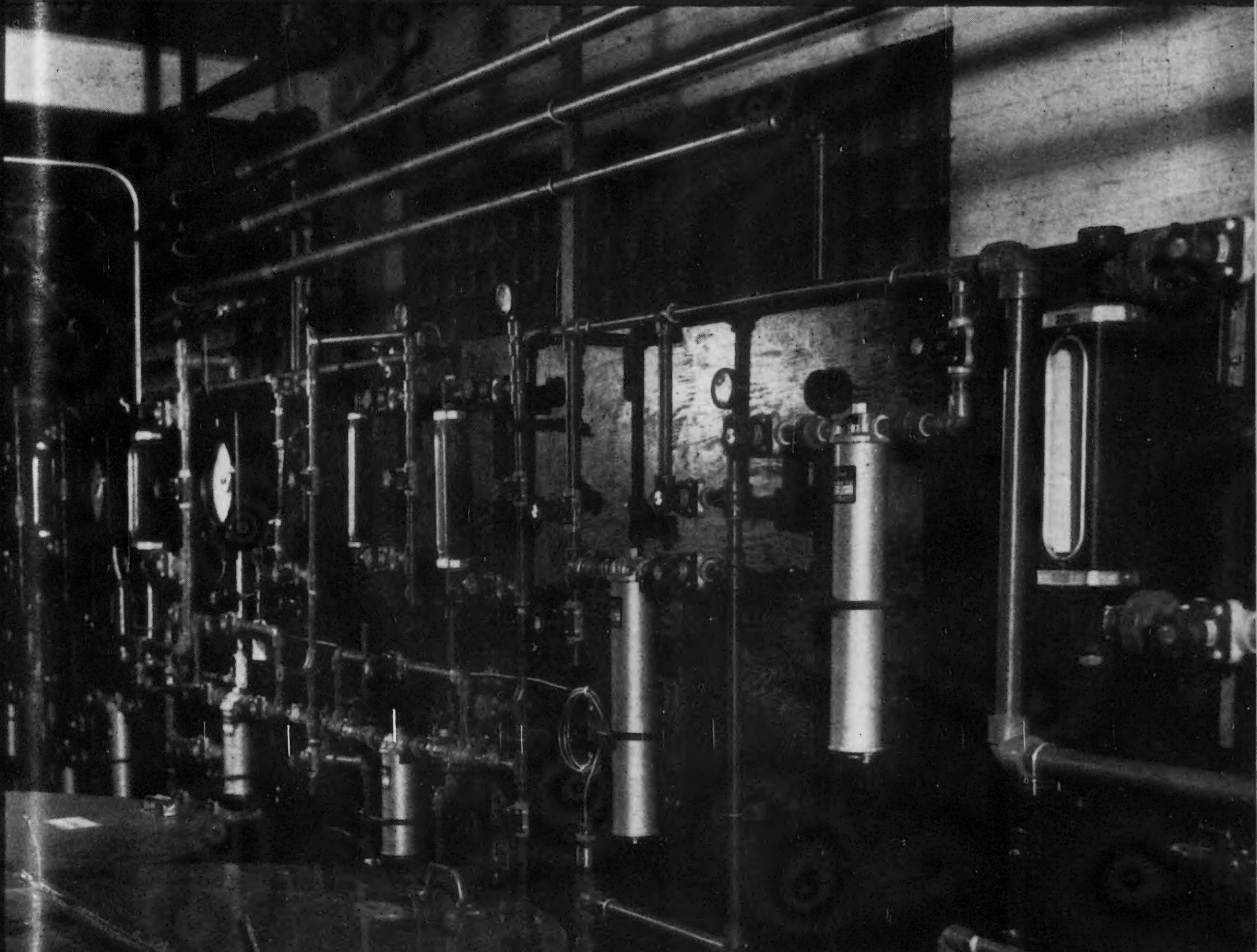
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



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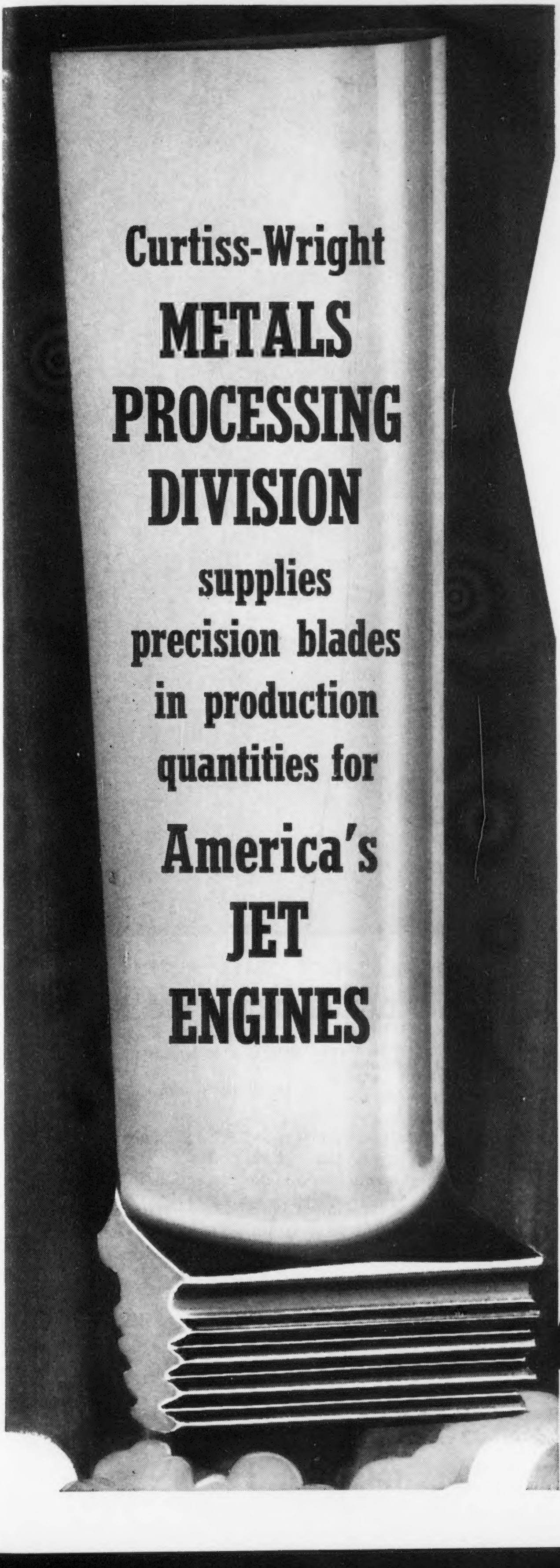

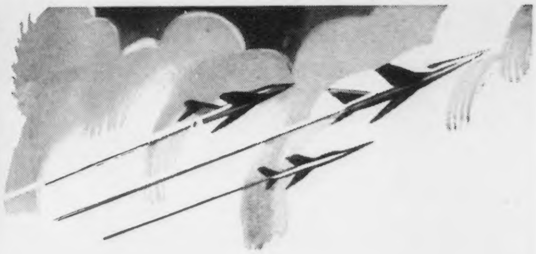

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Corrosion

devoted entirely to corrosion research and control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

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TECHNICAL SECTION

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Corrosion Is Indexed Regularly by Engineering Index.

How Corrosion Is Indexed

1. Alphabetical subject and author indexes are published in December.
2. Abstracts of Technical Articles appear in the Corrosion Abstracts Section.
3. Abstracts of articles appear in NACE Bibliographic Surveys of Corrosion.
4. Abstracts of articles are published in the NACE Corrosion Abstract Punch Card Service.
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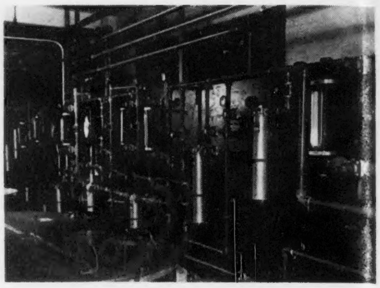

THIS MONTH'S COVER—The installation above shows a system of polyvinyl chloride pipe used in the replenisher, circulating system and storage tanks in the Pathecolor, Inc., Bayonne, N. J. plant for developing Eastman Kodachrome film. At least 10 years' service is expected from this piping.

☆

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PHOTOGRAPHY

New York World-Telegram
The Sun
NEW YORK, TUESDAY, DECEMBER 18, 1956
25

SECOND SECTION
EDITORIALS
SPORTS—FINANCE

Drive to Windy City on Turnpikes Now Is 13-Hour Breeze

With today's network of high speed turnpikes, Chicago is only 13 hours away for a New York motorist who wants to go west. The turnpike tour from New York to the Windy City is graphically shown above. Follow the dark line, from right to left, and you'll find the key mileage points, the times and the toll costs.

Map by Williams.

Ellenville Seeking Head for New Bank

Special to World-Telegram and Sun.
ELLENVILLE, N. Y., Dec. 18.—

shares, which were over-subscribed.

Brookville Police Official a Suicide

Special to World-Telegram and Sun.
SEA CLIFF, L. I., Dec. 18.—Gordon Hurley, 62, police commissioner of

Highway Building Has Come of Age, Quick Trip Shows

By SHELDON BINN,
Staff Writer.

The highway builders have caught up with the auto makers.

Proof? You can now drive from New York to Chicago without seeing a stop light and without crossing an intersection. You can make the run from city line to city line in 13 or 14 hours.

The trip really points up how much highway building has come of age. In preturnpike days it took the same time to drive to Pittsburgh—and that's only halfway to Chicago.

We know it can be done because we did it. This writer and photographer Ed Ford left New York at 5:20 a.m. (EST) and crossed the Chicago city line at 6:20 p.m. (EST), exactly 13

crossing the Susquehanna River just south of Harrisburg some 180 miles from New York.

On U.S. 22 the 110-mile drive from Harrisburg to Pittsburgh through the mountains was a real grind. The natural beauty of woods and hills was breathtaking. But so was the driving. For the most part you traveled a two-lane road, hunched over the wheel as you worked your way through the mountains. Before the N. Y. to Pittsburgh

A Famous Newspaper Tells the Story of Recent Engineering Achievement!

HERE'S A SIGNIFICANT STORY ABOUT ONE PHASE OF THIS TURNPIKE CONSTRUCTION

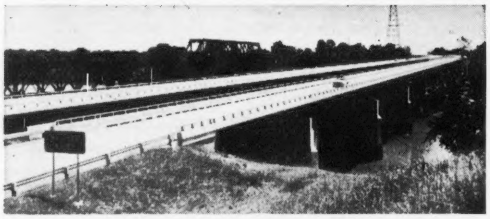
RED LEAD

Protects the 358 Bridges in Pennsylvania
Protects the 360 Bridges in Ohio
Protects the 312 Bridges in Indiana

That distinctive color of RED LEAD is a common sight wherever steel structures are being erected . . . bridges, factories, office buildings, hospitals, apartments . . . skeleton steel has that familiar coat. Over the years Red Lead has been the paint selected to protect iron and steel from corrosion and rightly so, as exhaustive outdoor exposure panel tests have proven its superiority over other pigments as a protective base coating.

While lead is recognized as one of the oldest of metals in the nonferrous field . . . its use dating back many centuries . . . it still holds its own with the "wonder" metals in our rapidly expanding economy due to its inherent properties and imperishable nature.

Bridge over the Delaware River



Bridge over the Maumee River, Ohio

Bridge over the Pidgeon River, Indiana

ST. JOSEPH LEAD COMPANY
The Largest Producer of Lead in the United States
250 PARK AVENUE, NEW YORK 17, NEW YORK

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(a) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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Corrosion

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An Association of Individuals and Organizations Concerned with Control of Corrosion

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Topic of the Month

Modern Cleaning Methods for Tankage Equipment

*By L. S. VAN DELINDER**

Introduction

THE CLEANING of tankage equipment involves the removal of six types of surface contamination. These may be classified as (1) water soluble light liquids, (2) light oils, (3) viscous water soluble materials, (4) heavy oils or greases, (5) solids, and (6) materials leaving a residual odor when removed. The terms light oils and greases are used here to designate all organic, water-insoluble materials.

Although certain of the water soluble compounds of categories 1, 3 and 5 present problems in providing the proper mechanical equipment for their removal, a clean surface can be produced with the use of a sufficient amount of hot water. Class 2 materials usually are removed without difficulty by steaming, alkali washing or in some few cases by solvent washing. Class 5 requires an appraisal of each separate problem and tests the ingenuity of a man in many instances to provide a rapid, economical cleaning method. Classes 4 and 6 present some of the most difficult and widespread cleaning problems. New methods and materials for removing these commodities from the surface of a vessel are always of interest.

Test Methods

The time consumed in evaluating cleaning methods in the field is costly. Consequently, some means of conducting exploratory tests in the laboratory are desirable. Such tests cannot actually duplicate the results of a field test but do indicate the more probable approaches to a cleaning problem.

Steaming of a vessel can be duplicated with fair accuracy in the laboratory by suspending specimens above a steam inlet in a glass kettle. The specimens must have sufficient surface area to allow some variation in conditions of exposure. Coupons measuring two by four inches have been found to be satisfactory. Needless to say, the surface of the coupon should be a close approximation of the surface to be cleaned.

Reproducing the cleaning effect of a rotating head impinging hot water on a tank surface is more difficult. Although more elaborate devices have been tried, the most satisfactory reproduction of this cleaning method has been achieved by the use of a conventional laboratory wash bottle. The specimens were suspended from a hook, the bottle filled with the cleaning solution and heated to the desired temperature and the air inlet of the bottle attached to an air supply of approximately two pounds. The orifice in the wash bottle was 0.05 inch in diameter. The tip of the nozzle was held one to two inches from the surface to be cleaned and the stream was moved about over the surface of the specimen for 10 seconds. The spray was repeated twice more at one minute intervals. The panels were then washed with cold water, allowed to dry and examined.

Non-Ionic Wetting Agent

The use of a non-ionic wetting agent in hot water was particuarly effective in removing oils and greasy materials from clean steel, rusty steel, aluminum and phenolic-coated surfaces by the spray method. The increased wetting action of the water containing this chemical increased the rate of penetration into the oil film resulting in a more rapid removal of the film. After breaking the film from the surface, the wetting agent apparently acts as an emulsifying agent to aid the water in carrying away greater quantities of the oil. Hot water (140 F) containing 0.1 percent of such a wetting agent was as good or better than ten commercial cleaning compounds. The small amount of wetting agent required reduced the price of this mixture considerably below that of the usual cleaning composition, most of which are aqueous solutions of about three percent of the cleaning agent. In removing 12 different viscous organic chemicals from the four types of surfaces, only one instance occurred which required increasing the wetting agent to three percent to clean the surface efficiently.

* Development Department, Carbide and Carbon Chemicals Company, South Charleston, W. Va.

The effectiveness of the hot water-detergent wash in cleaning the interior of tank cars was evaluated and found to be as successful as indicated by the laboratory tests.

Although the removal of water-soluble compounds from a surface was not investigated, the use of a small amount of wetting agent in a hot water wash probably would result in more rapid and efficient cleaning of a surface, particularly a rough or rusty steel surface.

Inverse Solubility

Care must be used in the selection of the wetting agent as many of the compounds have an inverse solubility in hot water. This is particularly true of those agents containing an aromatic structure. Nonionic wetting agents synthesized from secondary alcohols do not show such a pronounced inverse solubility in dilute aqueous solutions, and this may be one of the reasons why superior cleaning results for this service were achieved with this type of compound.

Of the ten commercial cleaning preparations chosen at random, four of the mixtures could not be used on aluminum surfaces at ambient temperatures and all of the compositions were too aggressive to serve as cleaning agents for a baked phenolic surface at 70 F. All contained an alkali salt of one type or another. Corrosion rates on aluminum 3003 were as great as 0.3 ipy at 70 F with severe pitting present.

Certain organic chemicals may be removed from a surface rather readily but leave an invisible residue which creates an odor problem. Both in the laboratory and in the field, only steaming was effective in removing the odor from a vessel previously exposed to these chemicals

Part 1 of 2 Parts

The Corrosion of Iron in High-Temperature Water★

Part 1—Corrosion Rate Measurements

By D. L. DOUGLAS* and F. C. ZYZES**

Abstract

A description is given of a new method of measuring the corrosion rate of metals in high-temperature water. Corrosion measurements were carried out in small autoclaves, the gas space of which was filled with a known amount of helium. After corrosion, a sample of the gas was taken and analyzed on a mass spectrometer. From the pressure, volume, temperature and analysis of the gas, the amount of hydrogen produced during the corrosion period could be calculated. This method was used in measuring the corrosion of Armco iron and high purity iron over the temperature range 240-360 C. The effects of surface finish, temperature and heat treatment were studied. In addition, measurements were made in saturated vapor, superheated vapor and certain dilute aqueous solutions. **4.6.5**

Introduction

THE REACTION between iron and ferrous alloys and water in the temperature range 200 to 374 C has been a problem of practical importance for many years, as the voluminous literature on boiler corrosion will attest. With the advent of power-generating nuclear reactors in which water is used as a primary coolant to transfer heat from the reactor to a heat exchanger or boiler, the problem has assumed new importance. The reason for this is that the possibilities of fouling of fuel element surfaces and deposition of radioactive corrosion products throughout the system put a severe upper limit on the amount of corrosion which can be tolerated. In order to maintain as clean a coolant system as possible, nuclear design engineers have been relying on highly alloyed steels such as the 300 series stainless steels. The development of a more easily fabricated and less expensive, yet sufficiently corrosion-resistant, ferrous alloy has lagged. This has come about mainly because of a complete lack of basic knowledge of the mechanism of the reaction between iron and pure water at these temperatures.

A program of study of the reaction between iron and water was undertaken in this laboratory to help rectify the above situation. This program consisted of three phases:

1. A study of the over-all rate of reaction between pure iron and pure water in the temperature range 240 to 360 C for times up to about 500 hours.
2. Kirkendall-type experiments to identify the ionic species which is diffusing through the oxide film formed in the reaction.
3. An investigation of the stability of ferrous hydroxide in high temperature water.

Only the first of these three phases will be reported here. The results of work on the remaining parts will be published at a later date.

Despite the avowed importance of the corrosion of iron in high-temperature water, the literature contains very few studies of the reaction between iron and water. The equilibrium was investigated thoroughly by Chaudron in his classic study in 1922.[1] Some years later Thiel and Luckmann determined the extent of reaction between iron powders and water, dilute sodium hydroxide, and solutions of various salts.[2] They determined the extent of reaction by measuring the amount of hydrogen evolved when iron powder was subjected to the test liquid at about 100 C. The reaction in deaerated distilled water, although initially very rapid, became very slow after about 50 hours. It was found that the presence of oxygen (air) in the water did not affect the rate or extent of reaction.

In dilute sodium hydroxide solutions (0.01 to 0.05 N) the initial reaction was less rapid, and total corrosion after 100 hours in these solutions was considerably less than that in distilled water. Corrosion in deaerated 2N sodium chloride and sodium sulfate was not very different from that in the pure water. Gould and Evans[3] investigated the corrosion of steel by boiling water and concluded:

> "Under anaerobic conditions the corrosion of steel by boiling water is of the hydrogen-evolution type, it soon stifles itself by the formation of a film, which is first probably ferrous hydroxide but is converted *in situ* to magnetite by interaction with water. Sodium hydroxide in the water does not significantly diminish the corrosion rate, whilst sodium chloride or sulfate does not seriously increase it."

Wickert and Pilz recently studied the reaction between water vapor and iron.[4] The method used was similar to that of Thiel and Luckmann in that the

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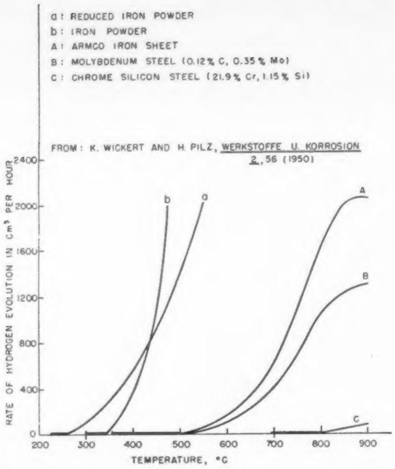

Figure 1—Temperature dependence of the water vapor-iron reaction for various metals.

amount of evolved hydrogen was used as a measure of corrosion. An essential part of their results is given in Figure 1, which originally appeared in their paper. From their work it is concluded that: (1) the finely divided iron reacts more readily than the massive material, (2) carbon steel behaves very much like iron at lower temperatures, and (3) highly alloyed steels are much more resistant to attack by water than ordinary steel or iron.

Wickert's conclusion[5] regarding the existence of a "Grenztemperatur" (i.e., a temperature below which no reaction takes place) for each material and surface condition thereof has been criticized by Werner.[6] Using Wickert and Pilz's data, Werner has calculated an activation energy of about 21 kcal per mole for the water vapor—iron reaction.[6,7] This is somewhat lower than the activation energy observed for the air oxidation of iron,[8,9] but it is of the right order of magnitude for a diffusion-controlled process.[10]

In this study the over-all rate of corrosion of pure iron in pure water in the temperature range 240 to 360 C was determined by measuring the amount of hydrogen evolved in the reaction. This measuring technique was adopted as the most accurate and reliable available. Previous experience with coupon weighing associated with descaling techniques[11,12] showed that these methods lack precision when applied to high-temperature water corrosion. In addition, the use of the hydrogen evolution technique made it possible to follow the corrosion of one specimen in a continuous fashion. The effects of surface finish and annealing as well as those of temperature were determined. Corrosion was measured also in saturated vapor, superheated vapor, and certain dilute aqueous solutions.

Experimental

Method

In general the procedure was to suspend iron coupons in a small (250 ml) autoclave containing a known amount of water adjusted to nearly fill the vessel and cover the specimens on heating to temperature. By means of a special valve arrangement the gas space in the autoclave was filled to a known pressure with helium. The autoclave was then placed in an oven maintained at the desired temperature. When the autoclave had been removed from the oven, cooling to room temperature was achieved by quenching in water.

After the autoclave had been shaken for about one-half hour by tumbling end-over-end at 20 rpm, it was attached to a vacuum system. The gas was expanded into an evacuated known volume, the pressure measured by a mercurial manometer, and a sample taken for analysis on the mass spectrometer. From the pressure, volume, temperature, and analysis of the gas, the amount of hydrogen produced during the corrosion period was readily calculated. For experiments on a continuous basis, the gas in the autoclave was pumped out and the cycle repeated. As described below, the reliability of the method was established by generating known amounts of hydrogen in the autoclaves by the reaction of weighed amounts of magnesium with the water.

Materials

Two sources of iron were used. The first was a hot-rolled Armco(1) iron strip 0.019 inch thick. In addition, the corrosion behavior of a high-purity vacuum-cast iron was studied. This Ferrovac E(2) was obtained as a centerless ground and annealed ingot 2 inches in diameter. Slices cut from this rod were cold-rolled to the desired thickness—usually 0.025 inch. Analyses of the two materials are given in Table 1. Vacuum fusion analysis of the Ferrovac E gave 142 ppm O_2, 9.0 ppm N_2, and 0.8 ppm H_2.

Coupons 1 inch by 4 inches were cut from the stock material, and a hole was drilled near one end. After being scrubbed with abrasive soap and water and dried, they were hand-polished under high-purity kerosene through No. 400 emery metallographic polishing paper. Degreasing was effected by rinsing in petroleum ether, washing with mild soap and deionized water, and rinsing with deionized water followed by a final rinse with absolute alcohol. Certain

(1) Trade name of the Armco Steel Co.
(2) Trade name of the Vacuum Metals Corporation.

TABLE 1—Analyses of Armco and Ferrovac E Iron

MATERIAL	Ni	Cu	Cr	Mn	Mo	Co	Al	Sn	Si	S	P	C	Fe (by Diff.)
Armco........	0.07*	0.10*	0.01*	0.04*	0.007*	0.006*	0.01*	0.02*	0.02*	0.020**	—	0.04**	99.65
Ferrovac E.... (Heat No. IC268)......	0.05** 0.02*	0.01** 0.001*	Tr** 0.002*	None** 0.0001*	0.01** 0.002*	—	—	—	0.04** 0.0003*	0.005**	0.002**	0.005**	99.88 to 99.97

Note: Values are in weight percent.
* Spectrographic Analysis.
** Chemical Analysis.

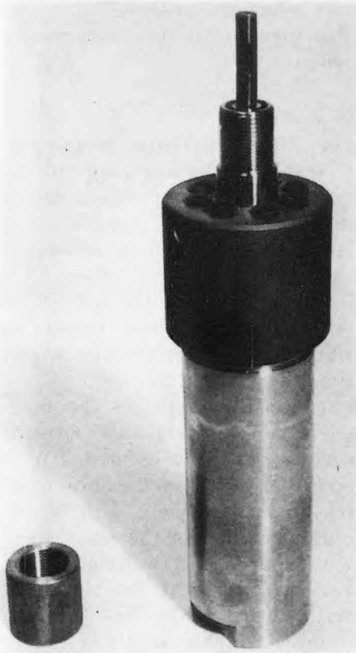

Figure 2—Modified 250-ml autoclave (assembled).

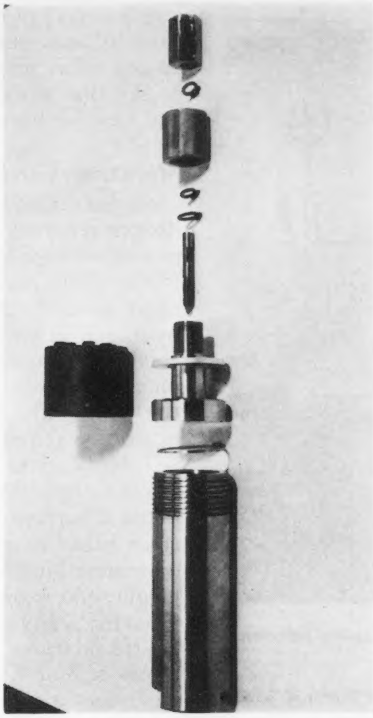

Figure 3—Modified 250-ml autoclave (disassembled).

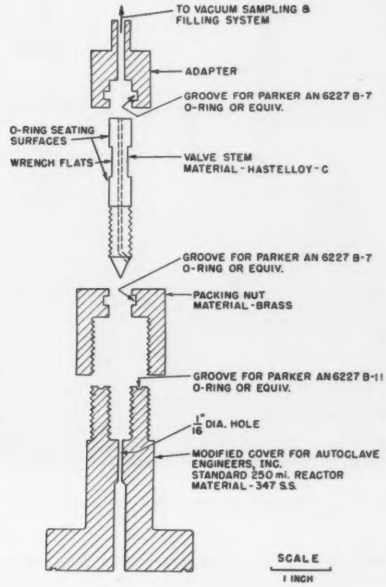

Figure 4—Exploded section of autoclave filling and sampling valve.

other less elaborate polishing procedures were tried in a few cases. In the majority of cases the mechanical polish was succeeded by electrolytic polishing by Jacquet's method[13] or chemical polishing in Marshall's solution.[14] After polishing, the coupons were rinsed thoroughly in distilled water and then with absolute alcohol, dried in air and stored in a desiccator until used.

The coupons were mounted in the autoclave by means of a stainless steel bolt through the hole. Two to four coupons were used in each test. They were insulated from one another and from the autoclave with small washers made from high-purity Al_2O_3 (pressed and fired at 1900 C) supplied through the courtesy of Dr. H. G. Sowman of the Ceramic Laboratory at Knolls Atomic Power Laboratory (KAPL). Preliminary work established the excellent corrosion resistance of the alumina.[12]

Purity of the water was maintained by passing the laboratory deionized water through a two-foot column of Duolite S-10 deoxygenating resin[(3)] and then through a trap bed of deionizing resin. The effluent water had a specific resistivity of less than one microhm cm and an oxygen content of less than 0.05 cc per liter as determined by the Winkler method. A brief exposure to the atmosphere attended filling the autoclaves, but resulted in no appreciable oxygen uptake of the water. It is estimated that less than one micromole of oxygen was present in the 100 to 150 ml of water used in each experiment. The helium used as a carrier gas showed less than 0.01 percent oxygen as analyzed on the mass spectrometer. The elaborate precautions to exclude oxygen were necessary since its presence might influence the iron-water reaction.

Apparatus

The autoclaves used throughout the work were modified versions of the 250-ml reactor assemblies sold by Autoclave Engineers, Inc., Erie, Pennsylvania. They were fabricated of Type 347 stainless steel, and gaskets of 18-8 stainless steel were used. Modification of the autoclaves consisted in substituting a specially machined top with a built-in valve arrangement for the standard top. Assembled and disassembled views of the autoclave and valve are shown in Figures 2 and 3, respectively. The principle on which the valve works can be seen in the exploded section (Figure 4). A carefully measured torque of 6 to 8 ft-lb was sufficient to seat the valve so that no leakage occurred at 360 C (2700 psi).

The gland nut and O-rings were removed, of course, when the autoclave was placed in the oven. The performance of these valves has been highly satisfactory. If the seat and point are properly polished, they have a life of several hundred cycles before needing rehoning.

Heating of the autoclave was accomplished in small vertical heat-treating furnaces supplied by the K. H. Huppert Co., Chicago, Illinois (Model PT 2222). Temperature was controlled by a "Pyrovane" controller.[(4)] However, the pressure indicated by a gauge connected to a water-filled autoclave located

(3) Manufactured by the Chemical Process Corp., Redwood City, California.

(4) Manufactured by the Brown Instrument Division of the Minneapolis Honeywell Regulator Company, Philadelphia, Pennsylvania.

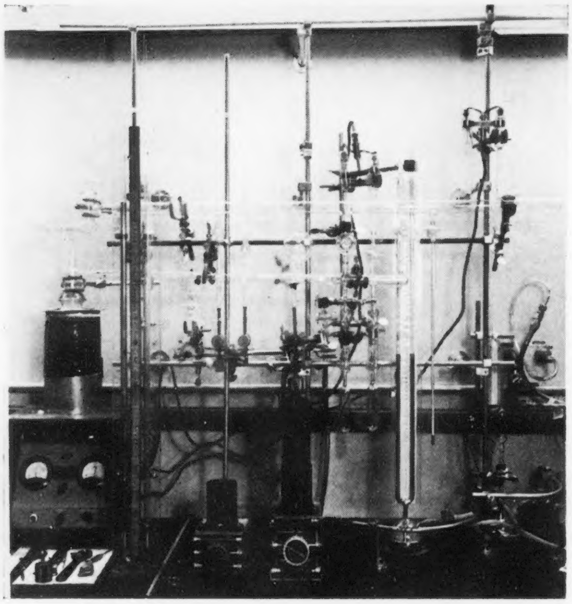

Figure 5—Vacuum system used for filling and sampling autoclaves.

TABLE 2—Hydrogen Recovery With Magnesium in Water at 316 C

Experiment	Hours at 316 C	Observed H_2 (moles x 10^3)	Blank Correction* (moles x 10^3)	Solubility Correction (moles x 10^3)	Corrected Observed H_2 (moles x 10^3)	Calculated H_2 (moles x 10^3)	Diff. %
15E	21	1.10	—0.04	+0.03	1.09	1.09_5	—0.5
15H	18	1.03	—0.03	+0.03	1.03	1.07	—4
21A	7	1.07	—0.02	+0.03	1.08	1.05	+3
21B	17	1.06	—0.03	+0.03	1.06	1.07	—1
21C	5	1.09	—0.02	+0.03	1.10	1.10	0
21D	20	0.91	—0.03	+0.02	0.90	0.90	0
21E	3	0.98	—0.01	+0.03	1.00	0.97_5	+2.5
					Average Diff.	....	1.6

* See page 23 for meaning and method of determination of hydrogen blank.

in the center of the oven was used as a more accurate indication of the temperature since the control thermocouples were located close to the heating elements. A temperature map of the oven showed a constant temperature to within ±1 degree C. Further details of the circuiting can be found in a previous report.[12]

The vacuum system by which the gas space was evacuated and filled with helium and later sampled is shown in Figure 5. In the photograph an autoclave is shown in position for sampling. To the left is the jack and adapter for filling and to the right of the autoclave are the sample bulbs.

All gas analyses were carried out on a General Electric analytical mass spectrometer. The reliability of this instrument for routine analyses of mixtures of the permanent inorganic gases is well established.[15] A precision of 1 percent is possible on repetitive measurements with the same or similar mixtures. When it is used in a routine way for a large variety of gases and mixtures, as in the case at KAPL, the emission and sensitivity fluctuate such that the precision becomes about 3 to 4 percent. At this value the analysis for hydrogen constitutes the largest single source of error in the method. From the standpoint of convenience and reliability it is far superior to any other method of hydrogen analysis. It is fair to say that without this instrument this work would not have been possible.

Magnesium Checks

As mentioned earlier, the reliability of the hydrogen recovery was established by carrying out the procedure with known amounts of magnesium metal, which reacts quantitatively to $Mg(OH)_2$ and H_2 in a short time. A calculation based on the solubility of hydrogen in water showed that if equilibrium were established with 150 ml of water in the autoclave, only 2.7 percent of the hydrogen would remain in the water. The possibility of a considerable supersaturation required that the method be checked.

Table 2 gives the results of several of the magnesium experiments. The average error of between 1 and 2 percent is in accord with an estimated total error based on the errors involved in the individual determinations of pressure, volume, etc. During the magnesium experiments, accuracy in the mass spectrometer analyses was ensured by running known H_2-He mixtures. It was discovered at this time that errors of 3 or 4 percent can arise from this source if this precaution of running known mixtures is not taken.

Sample Calculation

To illustrate further the basis of the method, the calculations for one experiment are carried out below:

	Experiment No. 21-A
Autoclave No. 8	
Volume	258 ml
Hydrogen blank[5]	0.003×10^{-3} moles H_2/hr
Autoclave filling	150 ml H_2O + 25.6 mg magnesium
Heated to 316 C for 7.3 hours	
Helium filling data	
Total pressure	818 mm Hg
Vapor pressure of water	26 mm Hg
Helium pressure	792 mm Hg
Gas volume	108 ml
Gas temperature	26.5 C
Gas amount	4.57×10^{-3} moles
Final helium data	
Total pressure	342 mm
Manifold volume	214 ml
Gas temperature	26 C
Gas in manifold	3.92×10^{-3} moles (a)
Water temperature	26 C
Water vapor pressure	25 mm
Autoclave gas pressure	317 mm
Gas in autoclave	1.83×10^{-3} moles (excluding water vapor) (b)

(5) See next section for full discussion of blank.

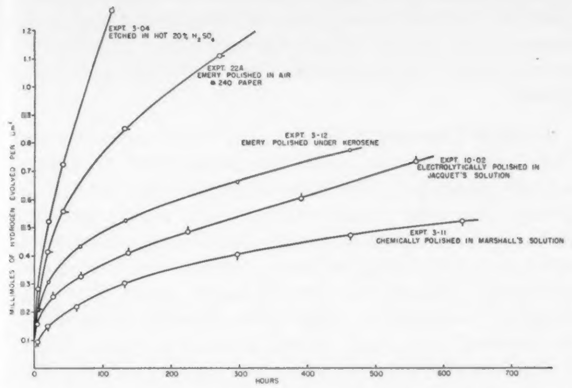

Figure 6—Effect of surface finish on corrosion of Armco iron in high temperature water (316 C).

Total gas	$(a + b) = 5.75 \times 10^{-3}$ moles
Gas analyses	$18.5_2\%$ H_2; $80.7_4\%$ He; 0.39% H_2O; 0.34% N_2
Final helium	4.64×10^{-3} moles
Helium recovery	101%
Observed amount of hydrogen	$1.06_6 \times 10^{-3}$ moles
Calculated hydrogen for magnesium	$1.05_2 \times 10^{-3}$ moles

A short discussion of the various errors is in order at this point. Pressures could be read in general to 0.5 mm, and volumes were known to within 1 ml. The fluctuations in room temperature were larger than is normal and in some cases may have amounted to 3 or 4 degrees C. Thus the total error in calculating the amounts of gas totaled about 1 percent from these sources.

It will be noted that the calculation of the final amount of gas was done in two parts, the manifold portion and the autoclave portion. Gas expanding past the autoclave valve into the evacuated manifold was assumed to have a uniform composition with regard to water vapor content, while the water vapor pressure in the autoclave gas space was assumed to be that corresponding to the temperature of the bulk water. In the case of continuous runs, the water vapor pressure was measured before the autoclave was refilled with helium. This value was then used to correct the final pressure of the previous run as well as the filling pressure of the new experiment. The gas analysis was reduced to a no water basis for calculating the amount of helium and hydrogen in the autoclave gas space portion since the vapor pressure of water was subtracted in calculating the total amount present. In every experiment the helium inventory was calculated; thus malfunctioning of the autoclaves was readily detected.

Hydrogen Blank

The autoclaves were fabricated of Type 347 stainless steel—a material which, after two to three thousand hours of exposure, reacts with high-temperature

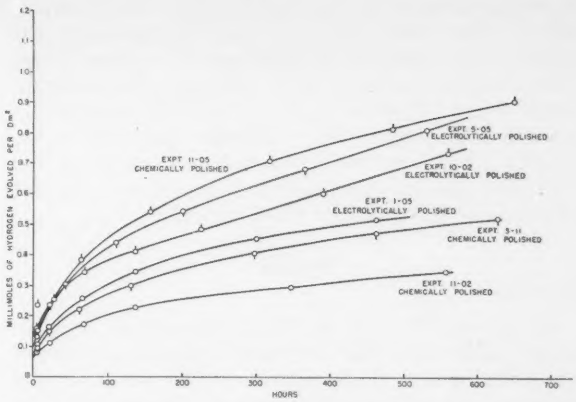

Figure 7—Corrosion of Armco iron in high temperature water (316 C)—electrolytically and chemically polished surfaces.

TABLE 3—Corrosion of AISI Type 347 Stainless Steel in High-Temperature Water

Auto-clave No.	Reaction Rate in Micromoles of Hydrogen Evolved per Square Decimeter Per Hour						
	Temp. (Degrees C)	Approximate Total Hours of Exposure					
		10	100	500	1000	2000	5000
3*	316	0.52	0.45	....	0.11	0.041	0.021
10**	316	15.4	4.2	0.94	0.33	0.057	0.023
11***	316	10.3	0.64	0.22	0.25	0.041	0.011

* Autoclave previously used for about 4000 hours and then cleaned by scrubbing with abrasive soap before being used in these experiments.
** New autoclave with machined inner surfaces degreased by scrubbing with abrasive soap.
***New autoclave with electrolytically polished inner surfaces.

water at a very low rate. However, it was not possible to neglect in general the hydrogen evolved in this reaction, since the internal autoclave area amounted to about 2.68 dm². Thus the autoclaves were "run in" for about a thousand hours before being used in this work. After that the "blanks" were determined before and after each corrosion experiment until they leveled off to a low value. From this point on, the "blanks" were checked at about three-month intervals. It was found that the rate of reaction of water with the autoclave walls remained constant as long as no vigorous cleaning methods were used. Hence the autoclaves were rinsed thoroughly between experiments but were not scrubbed or acid-cleaned. Only when the test specimens exhibited very low corrosion rates did the uncertainty in blank values contribute significantly to the total error in the calculated rates.

In the course of determining autoclave blanks, a very large amount of data on the corrosion rate of Type 347 stainless steel was obtained. Some of this is given in Table 3. The corrosion rate was found to be nearly independent of temperature in the range from 240 to 360 C. It is likely that the small temperature effects were masked by slight, but more important, variations in the amount of oxide scale adhering to the autoclave walls.

Hydrogen Dissolved in the Iron

To establish that negligible amounts of hydrogen were lost by solution in the iron, some small pellets

of Armco iron were corroded for about 150 hours at 600 C. After being removed from the autoclave, the pellets were analyzed for hydrogen by vacuum fusion. The assistance of Dr. W. S. Horton of the Metallurgical and Chemical Analysis Activity is gratefully acknowledged here. The maximum quantity of hydrogen which entered the metal as a result of the corrosion processes amounted to less than 1 percent of the total produced by these processes.

Results

General

Before the detailed results are presented, it is in order to describe the specimen appearance changes observed in a typical experiment. In all cases the original iron surface was covered with the thin invisible oxide film attendent either on the exposure of a freshly reduced surface to dry air or on the electrolytic or chemical polishing methods used. This film thickness ranges from 30 Å for the "air-formed film" on iron[16] to about 100 Å for the film on electrolytically polished specimens.[17] After an exposure of an hour or less to water at about 300 C the interference colors are observed. At ten hours the film is blue, and from the hydrogen evolved, a thickness of about 1000 Å is calculated.

Further exposure to the hot water results in a shiny black film; this situation persists for 150 to 200 hours, after which the film becomes dull black. No further change is observed up to 1500 hours—the longest exposure in this series of experiments. The dull black film appears porous in the outer layers, and with effort some of it can be removed by rubbing with a pencil eraser. Assuming that none of the oxide film is lost to the water, the evolved hydrogen corresponds to a thickness of about one micron for a typical dull black film at 500 hours' exposure. This calculation assumes also that the film has the bulk density of magnetite. It is interesting that these corrosion rates are of the same order as the rates of oxidation observed for pure iron in oxygen at the same temperature.[18, 19]

The technique used to follow the corrosion is continuous only in that the behavior of one specimen or set of specimens is followed for the desired length of time. In reality the method involves thermal cycling to the extent that the specimens are cooled for each hydrogen determination. However, no cracking or spalling of the thin magnetite scales was ever observed. It is believed that the results were not affected materially by this cycling. The observations of Gulbransen lend support to this assumption.[18]

Also noted about the appearance of the corroded specimens was that no pitting or other signs of localized attack were ever observed. Several of the corroded coupons were examined metallographically for indications of grain boundary corrosion, but none were found.

Armco Iron

Since Armco iron was the first material available for this study, it was used in testing the effects of several important variables on the corrosion rate. The variables investigated included surface treatment (determines true area), temperature, annealing treatment, phase (liquid, saturated vapor and superheated vapor), and dissolved salts. The results are presented below.

Surface Treatment. This variable was investigated first, principally in order to select the treatment which would give the most reproducible results. In going from the rough-etched and emery-polished surfaces to the smoother electrolytically and chemically polished surfaces the corrosion rate decreased markedly (Figure 6). In all cases metal that was pickled or etched in dilute acid or emery-polished in air showed very high initial corrosion rates. There is reason to believe that after sufficient time (i.e., 2000 hours) the corrosion rate of the etched specimens will decrease to about that of the smoother specimens.

That there is little difference between the electrolytically polished and chemically polished surfaces can be seen in Figure 6, and even more clearly in Figure 7. The latter figure shows the reproducibility of the measurements from one set of specimens to another. The spread is about a factor of 2 in total corrosion at the end of 500 hours, which is much larger than any experimental error. The point will be discussed in detail later. It is sufficient to state here that the variations are caused by slight differences in the metal surface (i.e., the surface finish and/or the extent of the initial oxide layer). In any case a very consistent pattern of behavior is obtained with the highly polished surfaces.

Temperature. Corrosion measurements were made at three temperatures—240, 316 and 360 C. The results of measurements with electrolytically and chemically polished specimens at 240 and 360 C are given in Figure 8. It appears that somewhat less corrosion takes place at the lower temperature, while the results at 360 C cannot be distinguished from those at 316 C (see Figure 7).

Another distinct feature of the corrosion behavior at the lowest temperature is that the time dependence is linear over nearly the entire range of the measurements. In contrast to this constant rate at 240 C the rate at the higher temperatures continually decreases with time.

Annealing Treatment. In reality at least three variables are involved in the annealing treatments investigated in this work: the metallographic state (grain size, degree of work hardening, etc.), initial surface oxide, and gas content (particularly hydrogen) of the metal. For the Armco iron 800 C was selected as the annealing temperature. The heat-treatment was carried out in an apparatus which could be either evacuated to less than 10^{-5} mm Hg or filled with pure dry hydrogen. After annealing, the coupons were stored in a desiccator before use. This ensured that the air-formed oxide film was present before exposure to the hot water. Since the growth rate of the film falls off rapidly after a few hours[16] and the storage time was of the order of days, all of the hydrogen-annealed coupons should have had approximately the same initial oxide film. The nature

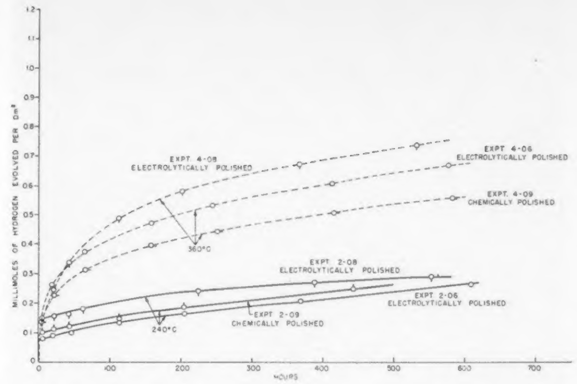

Figure 8—Corrosion of Armco iron in high temperature water at 240 C and 360 C.

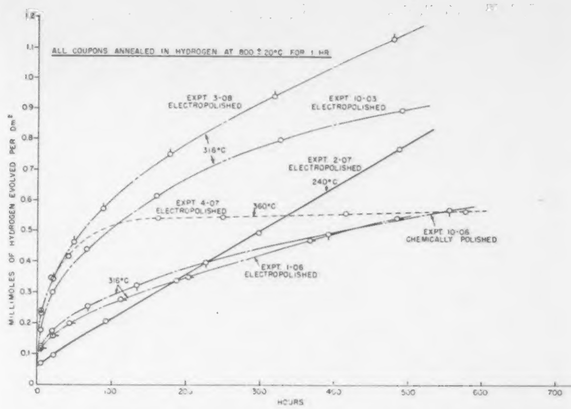

Figure 9—Effects of annealing in hydrogen for one hour at 800 C on corrosion of Armco iron in high temperature water.

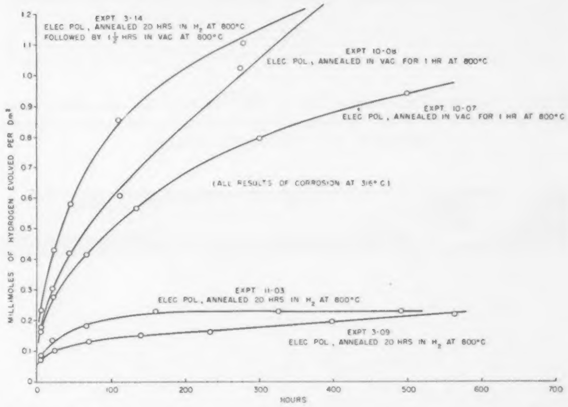

Figure 10—Effects of vacuum annealing and of annealing in hydrogen for 17-20 hours at 800 C on corrosion of Armco iron in high temperature water (316C).

of the surface of vacuum annealed material cannot be specified with certainty. It is likely that the oxide film present as a result of the polishing treatment is dissolved in the metal and that a fresh film appears on exposure to dry air at room temperature.

The principal difference between the vacuum-annealed and hydrogen-annealed metal is in the content of gas, particularly hydrogen. At 800 C in a vacuum the thin (0.015-inch) metal coupons were substantially degassed in less than one hour. Similarly the hydrogen-annealed coupons will be saturated with hydrogen in a short time. Some of this will be lost in cooling and storage, but from the literature the hydrogen content is estimated to be about two micromoles per 100 grams.[20] Changes in the metal structure due to the annealing treatments were determined by the usual metallographic methods.

Figure 9 presents results for coupons which were annealed in pure dry hydrogen for about one hour at 800 C. Most were corroded in water at 316 C although the results of one measurement at 360 C and one at 240 C are also given. The effects of this annealing treatment are not great; this can be seen by comparing them with the unannealed results. The experiment at 240 C gave an unusually high rate of corrosion, although the linear character of the time dependence is retained. The peculiar result at 360 C, in which the corrosion practically ceased, cannot be explained.

To investigate further the possible effects of heat-treatment, some coupons were annealed for short periods in a vacuum and others for longer periods in hydrogen. Figure 10 shows the results obtained when these coupons were exposed to water at 316 C. It is evident that the vacuum annealing, whether preceded by a hydrogen annealing or not, results in a marked increase in the corrosion rate. Conversely a long anneal in pure dry hydrogen effects a considerable reduction in the corrosion rate.

Some of the coupons were examined metallographically after corrosion. The structure of the metal is shown as follows: Figure 11—hot rolled condition as received; Figure 12—annealed one hour in hydrogen at 800 C; Figure 13—annealed one hour in vacuum at 800 C; Figure 14—annealed 21 hours in hydrogen at 800 C. Clearly the short (one-hour) annealing treatments effected little change in the metal structure. The longer anneals produced a noticeable grain growth and some spheroidization of the carbides.

Phase. Valuable information concerning the nature of the iron-water reaction may result from a study of the reaction in the vapor phase. To this end the results shown in Figure 15 were obtained. These are very similar to the results obtained in the liquid phase. In particular, the corrosion rate in superheated vapor is no greater nor less than in the saturated vapor or the liquid. The spread in the results obtained can be attributed for the most part to variations in surface condition.

Dissolved Salts. In order to establish that very small traces of dissolved salts or small shifts in pH toward the basic side were not influencing the corrosion measurements, the rate was determined in dilute sodium chloride, dilute sodium hydroxide, and water containing SiO_2. The first was chosen as a typical salt, and the second, to alter the pH; the silica was

Figure 11—Hot-rolled Armco iron in the "as received" condition. One percent nital etch, 250X. Specimen was electrolytically polished before annealing and subsequent corrosion.

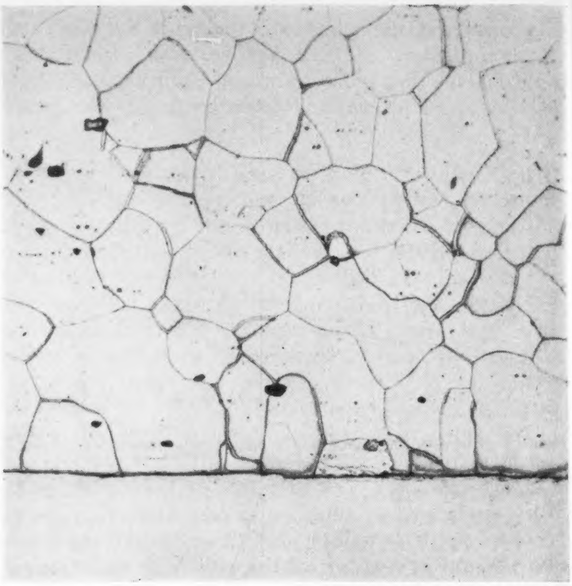

Figure 12—Armco iron annealed in hydrogen for one hour at 800 C. One percent nital etch, 250X. Specimen was electrolytically polished before annealing and subsequent corrosion.

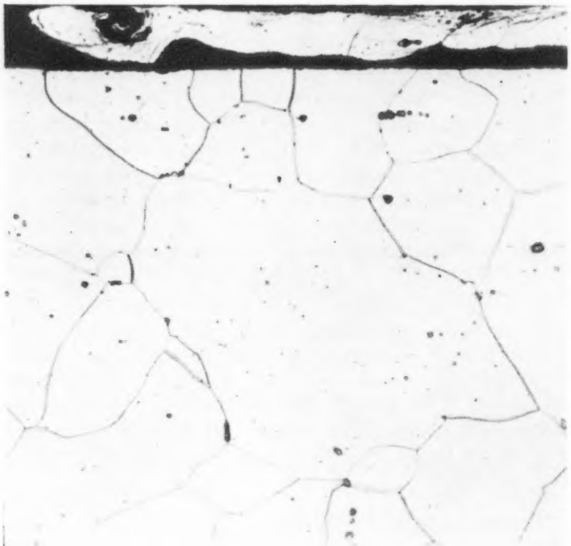

Figure 13—Armco iron annealed in vacuum for one hour at 800 C. One percent nital etch, 250X. Specimen was electrolytically polished before annealing and subsequent corrosion.

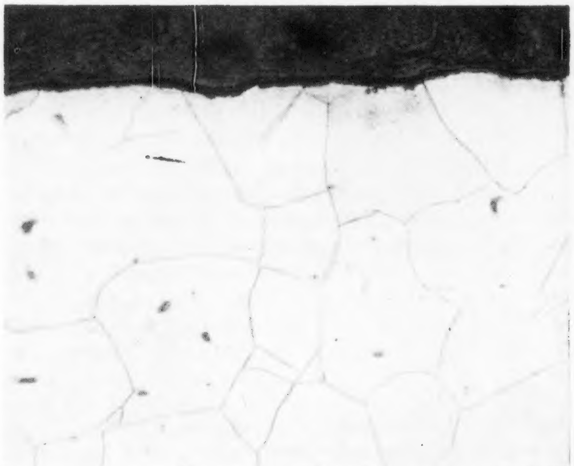

Figure 14—Armco iron annealed in hydrogen for 21 hours at 800 C. One percent nital etch, 250X. Specimen was electrolytically polished before annealing and subsequent corrosion.

selected as a likely contaminant and because it is used as an inhibitor in boiler practice. Figure 16 presents the results of these measurements. Again the spread is just about that obtained in the pure water.

High-Purity Vacuum-Cast Iron

The selection of high-purity vacuum-cast iron was based, of course, on a desire to eliminate possible effects of impurities in the metal on the corrosion rate. In general all of the coupons were electrolytically polished. A number of runs were made with cold-rolled material (rolled from 1/4 inch to about 0.025 inch) and the remainder with the rolled material which had been subjected to various annealing treatments.

Cold-Rolled. The rates of hydrogen evolution from five different sets of electropolished coupons exposed to water at 316 C are given in Figure 17. One of the experiments (12-06) was carried out with specimens rolled out to about 0.05 inch instead of the 0.025 inch used for the remainder. Comparing these results with the Armco iron (Figure 7) it appears that the

TABLE 4—The Iron-Water Reaction
Values of n in the Equation, $m = k_1t^n + k_2$

Experiment	Material	Surface Finish*	Annealing Treatment	Temp. (Degrees C)	n
4-06	Armco	e p	None	360	0.27
4-08	Armco	e p	None	360	0.30
4-09	Armco	e p	None	360	0.27
1-05	Armco	e p	None	316	0.31
5-05	Armco	e p	None	316	0.38
3-11	Armco	c p	None	316	0.35
11-02	Armco	c p	None	316	0.34
11-05	Armco	c p	None	316	0.41
3-08	Armco	e p	H_2, 1 hr, 800 C	316	0.38
10-03	Armco	e p	H_2, 1 hr, 800 C	316	0.35
10-06	Armco	c p	H_2, 1 hr, 800 C	316	0.35
1-06	Armco	e p	H_2, 1 hr, 800 C	316	0.35
10-07	Armco	e p	Vac, 1 hr.	316	0.40
3-14	Armco	e p	H_2, 17 hr, 800 C VaC, 1½ hr, 800 C	316	0.36
11-07	Armco	e p	None	316 (NaOH)	0.36
12-03	Armco	e p	None	316 (NaCl)	0.24
12-04	Armco	e p	None	316 (SiO_2)	0.27
1-09	Armco	c p	None	316 (Sat. vapor)	0.40
4-12	Armco	e p	None	360 (Sat. vapor)	0.32
4-14	Armco	e p	None	360 (2170 psi)	0.38
4-17	Armco	e p	None	360 (1850 psi)	0.36
3-10	High Purity Vac. Cast	e p	None	316	0.26
10-09	High Purity Vac. Cast	e p	None	316	0.34
10-10	High Purity Vac. Cast	e p	None	316	0.46
11-04	High Purity Vac. Cast	e p	None	316	0.35
12-06	High Purity Vac. Cast	e p	None	316	0.39
4-16	High Purity Vac. Cast	e p	Vac., 1 hr, 860 C	316	0.37
3-16	High Purity Vac. Cast	e p	H_2, 17 hr, 860 C	316	0.32
10-12	High Purity Vac. Cast	e p	H_2, 17 hr, 810 C	316	0.40
				Average	0.35
				Average error	±0.04

*e p =electrolytically polished.
c p =chemically polished.

TABLE 5—Comparison of Corrosion Rates of Carbon Steel and Armco Iron in Water at 600 F

	Corrosion Rates in mg/dm²/mo.*	
Time (Days)	Carbon Steel Bloom, Krufeld	Armco Iron Douglas, Zyzes
20	30	19
40	17	13
120	6	..
200	6	..

* Slopes taken from Experiment 11-05 and corrected to the units of Bloom and Krufeld according to 0.1 millimole $H_2/dm^2/100$ hrs equals 32 mg Fe/dm²/mo. This assumes that the corrosion product is Fe_3O_4.

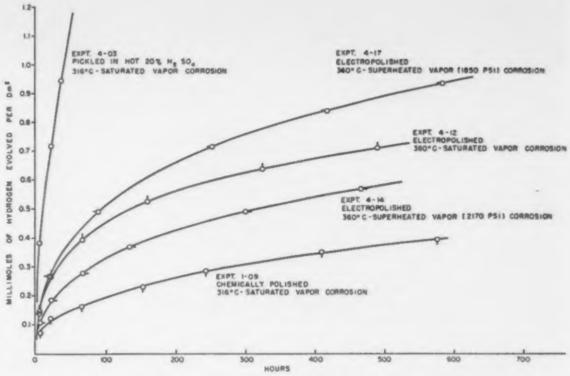

Figure 15—Corrosion of Armco iron in high temperature water vapor—comparison of saturated and superheated vapor.

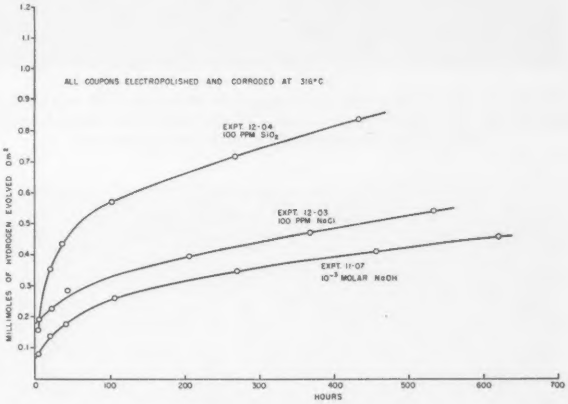

Figure 16—Corrosion of Armco iron in dilute aqueous solutions at high temperatures (316 C).

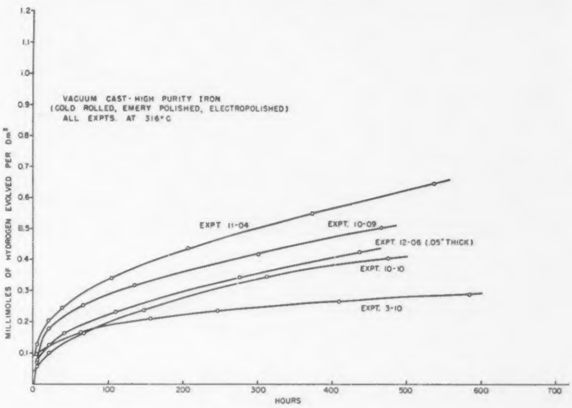

Figure 17—Corrosion of high purity iron in high temperature water (316 C)—cold-rolled and electropolished material.

spread is somewhat smaller, but the corrosion behaviors of the two materials are very much the same. Figures 18 and 19, which are photomicrographs of sections parallel to and perpendicular to the direction of rolling, respectively, show the high degree of cold work in the material.

Annealing Treatments. As in the case of the Armco iron, short annealing of the material produced a marked increase in the corrosion rate. This is shown in Figure 20 (compare with Figure 17). Here there seems to be no hydrogen effect as noted with the Armco. The corrosion rate is increased for all treatments. Representative metallographically polished and etched sections are shown in Figures 21 and 22. The very large growth of ferrite grains is observed. As in the case of the Armco iron, no sign of grain boundary attack was found in the metallographic observations.

Data Treatment

Having obtained the above described hydrogen evolution vs time curves, which correspond to the weight gain vs time information obtained in air

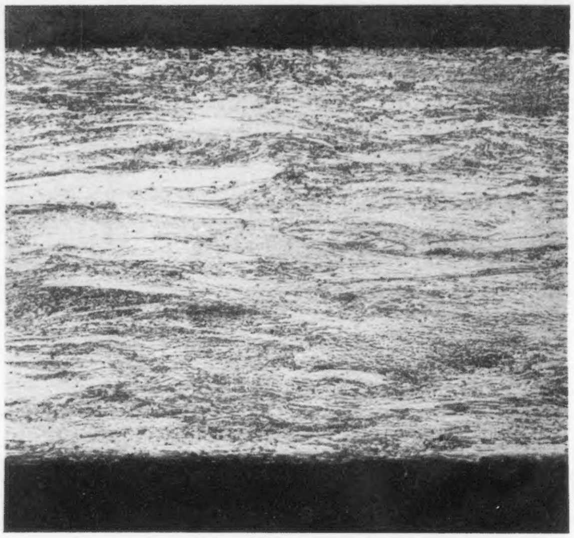

Figure 18—Cold rolled high purity iron with section parallel to direction of rolling. Three percent nital etch, 100X. Specimen was electrolytically polished before annealing and subsequent corrosion.

Figure 19—Cold rolled high purity iron with section perpendicular to direction of rolling. Three percent nital etch, 100X. Specimen was electrolytically polished before annealing and subsequent corrosion.

oxidation studies, attempts were made to fit the data to one of the well-established oxidation laws. In general, these did not meet with much success. The problem was straightforward in the case of the corrosion at 240 C; the linear law describes the behavior to a good approximation. Three tests for a fit to the parabolic law were tried: plotting m^2 vs t (m = millimoles of hydrogen evolved per dm^2 and t = hours), plotting t vs t/m as recommended by Moore,[21] and plotting log m vs log t. The results of the trials were uniformly negative; the iron-water reaction does not follow the parabolic law except possibly over a limited range of scale thickness. Similarly, attempts to fit the data to the direct logarithmic

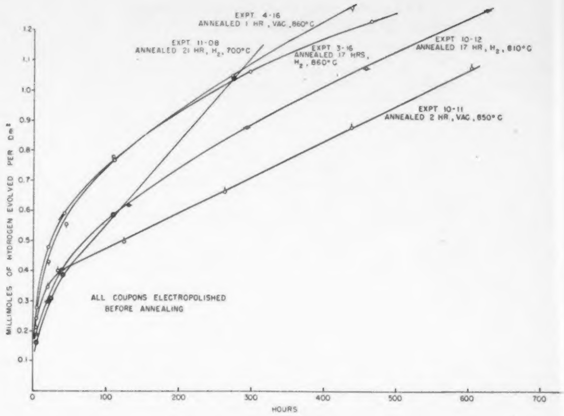

Figure 20—Effect of various annealing treatments on corrosion of high purity iron in high temperature water (316 C).

law by the method described by Champion and Whyte[22] and to the inverse logarithmic equation by an analogous method were fruitless.

The physical chemists' device, the log-log plot, did produce some valuable results. On such a plot all the data make fairly good fits to straight lines with slopes of about one-third. Some examples of this are given in Figures 23 and 24. From similar plots the data in Table 4 were obtained. It is apparent that the corrosion of iron in high-temperature water is best described by the cubic law, $m = k_1 (t + k_2)^{1/3} + k_3$. The spread in the results makes a determination of the constants of little value.

Discussion

In the introductory paragraphs the very limited amount of prior work on the iron-water reaction was mentioned briefly. No direct comparison of results with those studies is possible; however, there seems to be good qualitative agreement.

Very recently the reaction between carbon steel and water has been studied by Bloom and Krufeld[23,24] by an ingenious method. In their experiments small steel capsules containing water are welded shut and heated in an evacuated glass system to the desired temperature. As the corrosion proceeds in the capsules some of the evolved hydrogen effuses through the capsule wall. The pressure change caused by the accumulation of this hydrogen in the glass system is recorded and used as a measure of the rate of corrosion. There may be some question concerning the validity of a direct calculation of corrosion rate from the amount of effused hydrogen in the early stages, but after a steady state is reached the rate at which hydrogen comes through the metal must be equal to the rate of reaction of iron with water. A comparison of the results of Bloom and Krufeld with those of the authors is given in Table 5. In the present experiments the low corrosion rates are reached somewhat sooner than in the capsule experiment. It is noteworthy that Bloom and Krufeld's experiments have been extended to very long times and show a constant corrosion rate is reached after about 80 days (2000 hours).

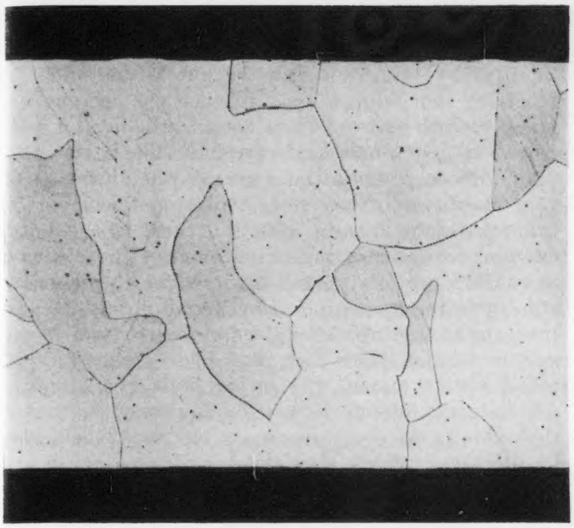

Figure 21—High purity iron annealed in vacuum for two hours at 850 C. Three percent nital etch, 100X. Specimen was electrolytically polished before annealing and subsequent corrosion.

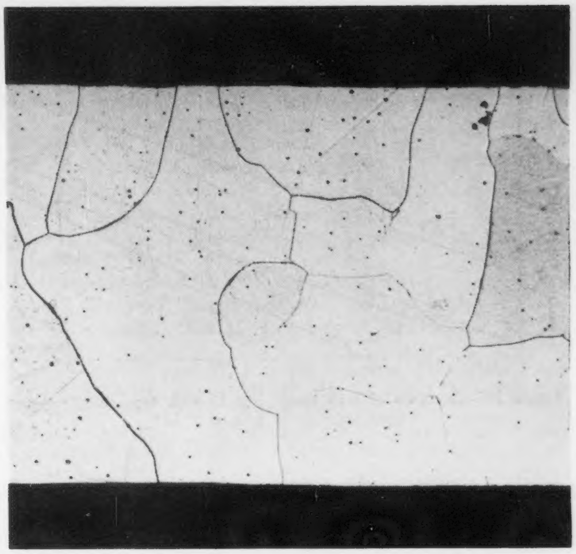

Figure 22—High purity iron annealed in vacuum for two hours at 850 C. Three percent nital etch, 100X. Specimen was electrolytically polished before annealing and subsequent corrosion.

Before proceeding with a discussion of the mechanism of the iron-water reaction it is important to point out that in the oxygen-free systems the reaction must proceed by a uniform oxidation-type attack. There is no question of local cell action of the type which produces pitting and other localized attack. Also, insulating the specimens from the rest of the autoclave prevented any general galvanic phenomena from influencing the corrosion rate. That local attack and galvanic effects were absent is proved by the following observations:

1. No evidence of pitting or other localized attack was found on careful examination of the coupons.
2. Virtually the same corrosion behavior is observed in saturated vapor and superheated vapor as in the liquid phase. The effects in question are almost certain to be absent in the superheated steam corrosion.
3. Large increases in the pH and dissolved salt content of the water do not alter the corrosion rate. An increase in localized attack and in galvanic effects would be expected with increasing conductivity of the water.

In addition to being consistent with the hydrogen evolution vs time data, any postulated mechanism must be in accord with a number of qualitative and quantitative observations on the iron-water reaction. The pertinent facts are these:

1. In dividing the over-all reaction into the separate anodic and cathodic reactions only a few possibilities exist. The possible anodic reactions are:

Ferrous hydroxide formation $Fe + 2OH^- \rightarrow Fe(OH)_2 + 2e^-$ (1)

Ferrous oxide formation $Fe + 2OH^- \rightarrow FeO + H_2O + 2e^-$ (2)

Ferrous ion formation $Fe \rightarrow Fe^{++} + 2e^-$ (3)

The eventual formation of magnetite probably takes place through a reaction of the type first suggested by Schikorr[25]

Magnetite formation $3\,Fe(OH)_2 \rightarrow Fe_3O_4 + 2H_2O + H_2$ (4a)

or

Magnetite formation $3\,FeO + H_2O \rightarrow Fe_3O_4 + H_2$ (4b)

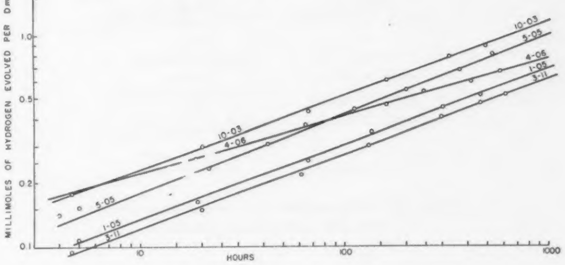

Figure 23—Corrosion of Armco iron in high temperature water—determination of n in $m = kt^n$.

In neutral or slightly basic solutions the passage of ferrous ions into solution may be neglected. The distinction between reaction (1) followed by (4a) and reaction (2) followed by (4b) is not realistic as the ferrous oxide is likely to be hydrated when first formed. In any event the distinction cannot be made without further information concerning the stabilities of the two species. The ensuing discussion will assume that ferrous hydroxide is the intermediate formed. In pure water the only possible cathodic reaction is the discharge of hydrogen ions.

Hydrogen gas formation $2H^+ + 2\,e^- \rightarrow H_2$ (5)

2. The oxide film passes through the usual interference color region to a shiny black as it increases in thickness. After long times the outer layer becomes dull black with the appearance of porosity.

3. Valuable clues concerning the nature of the reaction may be obtained by reasoning by analogy from the well-understood scaling of iron in air and oxygen. Certainly the mechanisms which are important there must play some part in the oxidation of iron by water. Conflicting views are expressed in the literature concerning the oxidation of iron at low temperatures. Vernon and coworkers[26] studied the oxidation of abraded mild steel and concluded that above 200 C (392 F) the oxide growth on iron in air or oxygen is due predominantly to the diffusion of iron ions outward through a layer of cubic

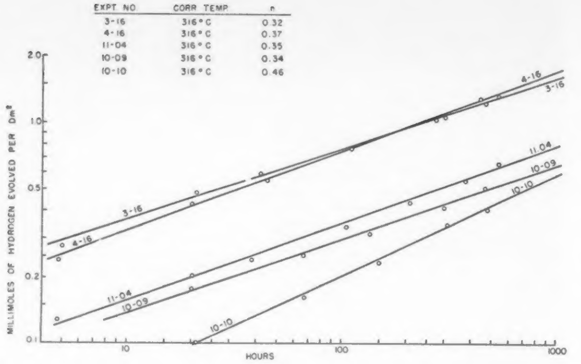

Figure 24—Corrosion of high purity iron in high temperature water—determination of n in $m = kt^n$.

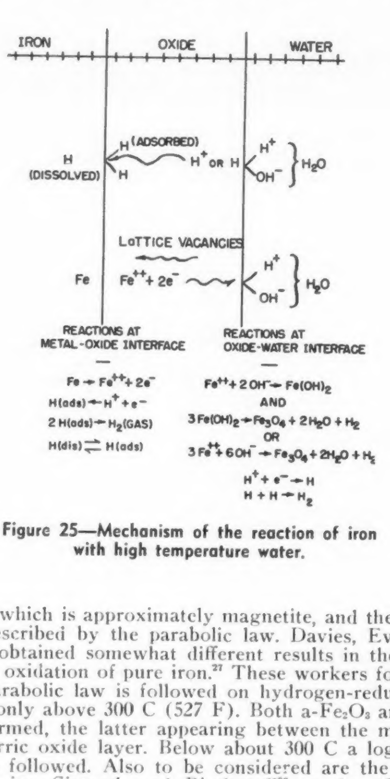

Figure 25—Mechanism of the reaction of iron with high temperature water.

oxide which is approximately magnetite, and the kinetics are described by the parabolic law. Davies, Evans, and Agar obtained somewhat different results in their study of the oxidation of pure iron.[27] These workers found that the parabolic law is followed on hydrogen-reduced surfaces only above 300 C (527 F). Both a-Fe_2O_3 and Fe_3O_4 are formed, the latter appearing between the metal and the ferric oxide layer. Below about 300 C a logarithmic law is followed. Also to be considered are the findings of Davies, Simnad, and Birchenall[28] to the effect that diffusion in magnetite is predominently cationic.

Kirkendall-type experiments which will be described in Part 2 of this report have shown that iron ions are diffusing through the oxide film formed in the water oxidation of iron. As mentioned in the introductory section, the activation energy derived by Werner[6, 7] from Wickert and Pilz's data[4] is in the range found for the air oxidation of iron where iron ion diffusion is rate controlling.

4. Although it is valuable to compare the iron-water reaction with the air oxidation, it must be considered that there is an important difference, namely, hydrogen is evolved in the reaction. This hydrogen is released into the solution and also is absorbed into the metal.[9] This behavior is fairly general with aqueous corrosion of metals. The nature of the system (i.e., solubility of hydrogen in the metal, hydride formation, etc.) determines the fraction of the total hydrogen which remains in the metal. In the case of iron the solubility is very low and no stable hydrides are formed; thus only a small fraction of the hydrogen enters the metal.

Based on the above information, the mechanism can be described as follows: Ferrous ions formed at the metal-oxide interface diffuse through the oxide (Fe_3O_4) by migration into vacant lattice sites. On reaching the oxide-water interface the ferrous ions combine with hydroxyl ions (or absorbed water molecules) to form ferrous hydroxide. The latter compound decomposes into magnetite, water, and hydrogen. To maintain electrical neutrality, electrons migrate with the ferrous ions and there is a countercurrent diffusion of lattice vacancies. The electrons neutralize protons at the oxide-water interface, resulting in the formation of hydrogen atoms. Most of these hydrogen atoms will combine to form hydrogen molecules. The fact that hydrogen enters the metal lattice means that either hydrogen atoms or protons must migrate from the water interface through the oxide to the metal interface. No good basis exists for deciding which species of hydrogen permeates the film. If the film is permeable to protons, some of these will be discharged at the metal-oxide interface, forming hydrogen atoms which then enter the metal. A pictorial presentation of this oxide film growth mechanism is given in Figure 25.

It is believed that the postulated mechanism is consistent with the known facts about the iron-water reaction. The hydrogen evolution vs time data obtained in experiments are interpreted as follows:

1. At 240 C and below the rate-controlling step is Schikorr's reaction. This reaction has been thought to play an important role in boiler corrosion for many years.[30, 31]

2. At higher temperatures, 316 and 360 C, the situation appears considerably more complicated. If the diffusion of iron ions were rate-controlling, a parabolic law and a decided increase in corrosion rate on going from 316 to 360 C would be expected. The spread in the data might be masking the temperature effect. However, if the activation energy is close to 20 kcal/mole, as the data of Wickert and Pilz indicate, the temperature effect should show up even with the data variation obtained. It is likely that some further and unknown factor is complicating the mechanism. The work on the oxidation of iron in air and oxygen.[26, 27] shows that peculiar effects can be expected in this temperature range. It may be that in this particular case no particular significance is to be attached to $n = 1/3$ (i.e., it may be the result of coincidence).

   Evans[32] expresses the view that the cubic law may be expected by coincidence to represent the facts of an oxidation process within experimental error over a limited range. This can easily be the situation in the iron-water reaction as studied here, since, although the time intervals involved are long, the range of film thicknesses covered in these measurements is relatively small, from about 0.1μ to 1μ.

   Hauffe and co-workers[33, 34] have developed a theoretical derivation of the cubic law for oxidations in air and oxygen, of which there are some examples in the literature.[35, 36] This derivation postulates a surface charge on the oxygen-oxide interface due to chemisorbed oxygen. The surface charge induces a "space-charge" in the oxide which decreases the diffusion rate. As such the mechanism cannot apply in the water oxidation. However, one possibility is that a layer of adsorbed hydroxyl ions has a similar effect in decreasing the diffusion rate of the iron ions.

3. The work of Bloom and Krufeld shows that a constant corrosion rate is reached after long exposure. This is most easily accounted for by assuming that on reaching

a critical thickness the outer layers of the oxide film become porous and no longer offer a diffusion barrier. Thus a barrier of approximately constant thickness is reached, and the corrosion rate will be constant. In fact, such a sublayer has been observed by Collongues, Sifferlen, and Chaudron[37] for the oxidation of iron in H_2-H_2O mixtures at 800 C.

The possible effects of the absorbed hydrogen on the corrosion rate cannot be specified at this time. There is abundant evidence that the presence of hydrogen in iron can alter its electrochemical behavior. Patrick and Thompson[38] report on the effect of occluded hydrogen on the standard electrode potential of the iron-ferrous ion couple. Uhlig[39] has observed that hydrogen (from cathodic charging) diffusing through chromium steels makes the electrode potential more negative by as much as 100 millivolts. A comprehensive investigation of the effect of dissolved hydrogen on the corrosion behavior of iron and steel is very much needed.

A few comments on the observed spread in the hydrogen evolution results are in order here. It was noted earlier that the difference in corrosion of seemingly identical specimens was considerably larger than could be accounted for by any errors in the method. The most likely explanation of the variations is simply that the initial surfaces were not identical in amount of initial oxide film. It does not seem probable that differences of a factor of 2 in true surface area are involved. If this initial oxide film controls the rate of diffusion, the kinetics of the overall oxidation of iron by water will be affected at one stage by the rate at which this film rearranges to a form that is stable in the high-temperature water rather than stable in air.

Acknowledgment

The assistance of the KAPL Metallurgical and Chemical Analysis Activity in performing the metal analyses and, in particular, the innumerable gas analyses is gratefully acknowledged. Special thanks are due Dr. H. C. Mattraw, C. F. Pachucki, and L. Yetter for their constant efforts to ensure the highest possible accuracy in the mass spectrometer analyses.

References

1. G. Chaudron. *Z. Elektrochem.*, **29**, 279 (1923); *Ann. Chemie*, **16**, 221 (1921).
2. A. Thiel and H. Luckmann. *Korrosion u. Metallschutz*, **4**, 169 (1928).
3. A. J. Gould and U. R. Evans. *J. Iron and Steel Inst.*, **155**, 195 (1947).
4. K. Wickert and H. Pilz. *Werkstoffe u. Korrosion*, **1**, 56 (1950).
5. K. Wickert. *Werkstoffe u. Korrosion*, **3**, 17 (1952).
6. M. Werner. *Werkstoffe u. Korrosion*, **3**, 333 (1952).
7. M. Werner. *Werkstoffe u. Korrosion*, **6**, 113 (1955).
8. J. K. Stanley, J. von Hoene and R. T. Huntoon. *Trans. Am. Soc. Met.*, **43**, 426 (1951).
9. E. A. Gulbransen. *Trans. Electrochem. Soc.*, **91**, 573 (1947).
10. O. Kubaschewski and B. E. Hopkins. Oxidation of Metals and Alloys. London: Butterworths Scientific Publications, 1953, p. 162.
11. R. Fowler, Jr., D. L. Douglas and F. C. Zyzes. "Corrosion of Reactor Structural Materials in High Temperature Water. I. Descaling Methods," KAPL-1198, August 27, 1954.
12. R. Fowler, Jr., D. L. Douglas and F. C. Zyzes. Corrosion of Reactor Structural Materials in High Temperature Water. II. Static Corrosion Behavior at 600 to 680 F, KAPL-1248, December 1, 1954.
13. C. J. Smithells. Metals Reference Book. New York: Interscience Publishers, Inc., p. 239.
14. W. A. Marshall. *Research*, **7**, 89 (1954).
15. Mass Spectrometry. Vol. 1, No. 2, May 1951, Schenectady, New York: General Electric Co., 1951.
16. A. B. Winterbottom. *J. Iron and Steel Inst.*, **165**, 9 (1950).
17. E. J. Caule and M. Cohen. *Can. J. Chem.*, **31**, 237 (1953).
18. E. A. Gulbransen. *Trans. Electrochem. Soc.*, **91**, 573 (1947).
19. D. E. Davies, U. R. Evans and J. N. Agar. *Proc. Roy. Soc. London*, **A225**, 443 (1954).
20. M. H. Armbruster. *JACS*, **65**, 1043 (1943).
21. W. J. Moore. *J. Electrochem. Soc.*, **100**, 302 (1953).
22. F. A. Champion and M. J. Whyte. *J. Inst. Metals*, **75**, 737 (1949).
23. M. C. Bloom and M. Krufeld. Nuclear Power Progress Report (NRL Report 4350). Washington, D. C.: Naval Research Laboratory, March 1954, pp. 48-61.
24. NRL Quarterly Report on Nuclear Science and Technology. Washington, D. C.: Naval Research Laboratory, October 1954, *et seq.*
25. G. Schikorr. *Z. Electrochem*, **35**, 65 (1929); *Zeit. Anorg. Chem.*, **212**, 33 (1933).
26. W. H. J. Vernon, et al. *Proc. Roy. Soc. London*, **216A**, 375 (1953).
27. D. E. Davies, U. R. Evans and J. N. Agar. *Proc. Roy. Soc. London*, **225A**, 443 (1954).
28. M. H. Davies, M. T. Simnad and C. F. Birchenall. *J. Met.*, **5**, 1257 (1953).
29. F. J. Norton, *J. Applied Phys.*, **11**, 262 (1940).
30. U. R. Evans. Metallic Corrosion Passivity and Protection. London: Edward Arnold and Co., 1946, p. 209.
31. U. R. Evans. *Engineering*, May 8, 1953
32. U. R. Evans. *Rev. Pure and Applied Chem.*, **5**, 1 (1955).
33. E. J. Engell, K. Hauffe and B. Ilschner. *Z. Elektrochem.*, **58**, 478 (1954).
34. K. Hauffe. *Werkstoffe u. Korrosion*, **6**, 117 (1955).
35. J. T. Waber. *J. Chem. Phys.*, **20**, 734 (1952).
36. K. Hauffe and P. Kofstad. *Z. Elektrochem.*, **59**, 399 (1955).
37. R. Collongues, R. Sifferlen and G. Chaudron. *Rev. Met.*, **50**, 727 (1953).
38. W. A. Patrick and W. E. Thompson. *JACS*, **75**, 1184 (1953).
39. H. H. Uhlig, N. F. Corr and P. H. Schneider. *Trans. Electrochem. Soc.*, **79**, 11 (1941).

DISCUSSION

Question by D. J. DePaul, Westinghouse Electric Corporation, Large, Pennsylvania:

Different corrosion rates were given for samples with different surface finishes. Was any work done to determine if there was any relation to the total amount of corrosion and the actual surface area as determined by adsorption?

Reply by D. L. Douglas and F. C. Zyzes:

No determinations were made of true surface area by adsorption measurements. Assuming that one could carry out the corrosion measurements without exposing the samples to air, this would be a very interesting and worthwhile experiment.

Comment by Herbert H. Uhlig, Massachusetts Institute of Technology, Cambridge, Massachusetts:

It would seem from the results of this paper and that of Messrs. Bloom, Krufeld, Fraser and Vlannes that sodium hydroxide added to deaerated water has little effect on the corrosion of iron at elevated temperatures. These results appear to contradict the present practice of adding alkalis to boiler water.

Reply by D. L. Douglas and F. C. Zyzes:

Within the limits of the experimental conditions covered in this work, namely, pure iron, oxygen-free water, temperature 240-360 C, and static conditions, small concentrations of sodium hydroxide of the order of 10^{-3} molar have no effect on the corrosion rate. In terms of the suggested mechanism for the scaling of iron it is difficult to see how hydroxyl ion can influence the rate. At lower temperatures where Schikorr's reaction may be rate controlling we have evidence that high pH may decrease the corrosion rate (F. J. Shipko and David L. Douglas, Journal of Physical Chemistry, in press). With regard to boiler practice, sodium hydroxide additions are probably advantageous where oxygen scavenging is not complete.

End of Part 1

Part 2 will be published in the July, 1957 issue

Any discussions of this article not published above will appear in the December, 1957 issue.

Corrosion of Stainless Steels In Supercritical Water*

By W. K. BOYD and H. A. PRAY

Introduction

THE CORROSION of iron-base alloys in water and steam at elevated temperatures and pressures has long been an important problem. However, with the advent of water-cooled nuclear reactors, and the trend toward higher temperatures and pressures in steam power plants, the problem has assumed new significance. Although considerable information is now available concerning the behavior of stainless steels in high-purity water, the literature contains only a few references to corrosion studies conducted at temperatures above the critical temperature of water.

The present investigation was undertaken to determine the corrosion resistance of a number of the stainless alloys to supercritical water. The initial phase of the program covered an evaluation of some 12 alloys in degassed supercritical water at temperatures ranging from 800 F to 1350 F. In addition, the corrosion behavior of selected materials was determined in degassed water at 1000 F in the presence of hydrogen. The program also included a limited study of the effect of applied stress on corrosion resistance.

Materials and Test Procedure

Twelve commercial stainless alloys were selected for study. These provided a wide range of composition and included both hardenable and nonhardenable grades. The alloys investigated and typical analyses are listed in Table 1.

Test specimens approximately 1½ by ½ by 1/16 inch were prepared from heat-treated sheets of each material. The hardenable grades (AISI Type 410, Allegheny A-286, Armco 17-4PH, and Armco 17-7PH) were solution treated and aged according to recommended procedures, while the alloys of the AISI Type 300 series were quench annealed from 2000 F. Heavy scale and surface imperfections were removed by machining. A final finish was obtained by hand abrading on 120-grit paper. Prior to exposure, each sample was degreased in acetone and weighed.

Stress samples consisted of 6-inch lengths of ½-inch-OD tubing sealed in a jig (Figure 1) so that the pressure differential at temperature between the outside and inside of the tube provided a constant load. By varying the wall thickness over a 2-inch gauge length, the desired stress levels were attained.

Corrosion tests were conducted in ¼- and 1-liter stainless steel autoclaves employing a modified Bridgeman-type closure. The small autoclaves were constructed of Type 347 stainless steel, while the large autoclaves, designed to operate at 1350 F and 5000 psi, were made of Timken 16-25-6 alloy. An exploded view of the 1-liter autoclave assembly is

★ Submitted for publication March 5, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

WALTER K. BOYD, a project leader of the Corrosion Technology Division, Battelle Memorial Institute, holds a degree in metallurgical engineering from the Ohio State University and has specialized in metallurgical aspects of corrosion since 1945. He has had considerable experience in the development of special alloys and has contributed significantly to the development of both low and high temperature corrosion-resistant stainless steel alloys. Lately he has been active in the development of corrosion-resistant uranium and zirconium materials. Mr. Boyd is a member of NACE.

H. A. PRAY, Assistant Technical Director, has been connected with much of Battelle Institute's research in physical chemistry and corrosion technology since 1934. He is particularly known for the work he has done on fundamentals of corrosion and on the development of electrochemical techniques. He has likewise contributed substantially to knowledge of corrosion-resistant metals and alloys and to the techniques used for their evaluation. He received his BA and MA degrees in chemistry from Oberlin College. His doctorate work was completed at the University of Wisconsin in 1925. Dr. Pray is the author of numerous technical articles and is a member of a large number of technical organizations.

Abstract

The behavior of stainless steels, including both hardenable and nonhardenable grades, in degassed supercritical water at 800, 1000, and 1350 F and a pressure of 5000 psi is described.

In general, the corrosion at 1350 F observed for the alloys was found to be intergranular, while at 1000 F, only Inconel X exhibited selective penetration along grain boundaries. All alloys suffered some decarburization and carbide precipitation after exposure to supercritical water at 1350 F. No significant phase changes were observed at 800 and 1000 F.

The Armco 17-4PH, Armco 17-7PH, and Hastelloy F alloys were the most resistant materials at 1350 and 1000 F. All of the alloys evaluated had excellent resistance to 800 F degassed supercritical water.

The AISI Type 316 material was shown to be susceptible to stress-corrosion cracking at 1350 F.

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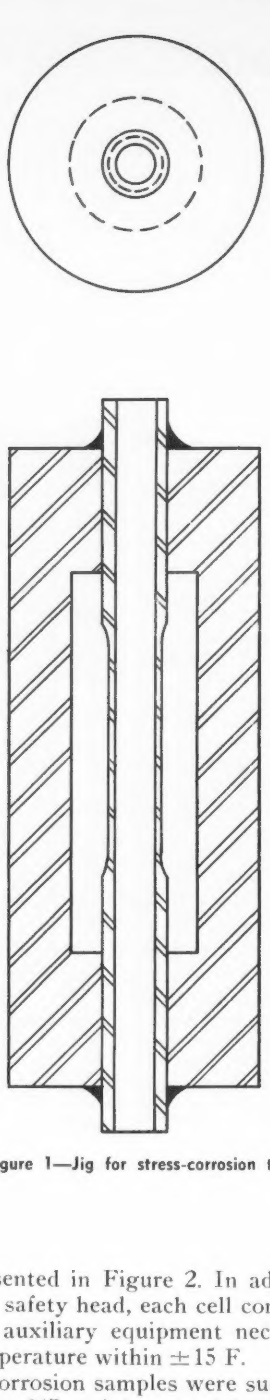


Figure 1—Jig for stress-corrosion test.

Figure 2—Exploded view of 1-liter stainless steel autoclave.

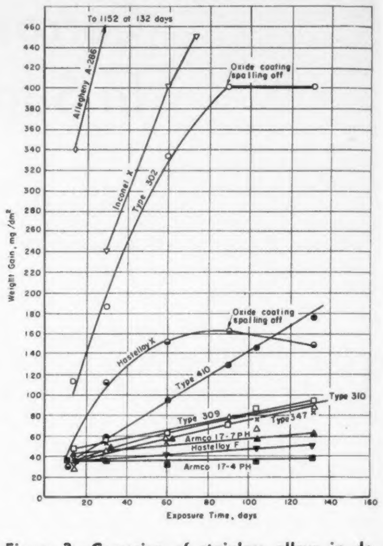


Figure 3—Corrosion of stainless alloys in degassed supercritical water at 1350 F and 5000 psi.

presented in Figure 2. In addition to the autoclave and safety head, each cell consisted of a furnace and the auxiliary equipment necessary to maintain the temperature within ±15 F.

Corrosion samples were suspended individually on Type 347 stainless steel hooks from racks attached to the "bomb" head. Care was taken to prevent the samples from touching each other or the walls of the autoclave. Prior to heating, each autoclave containing the specimens and the desired amount of boiled deionized distilled water (1,000,000 ohm-cm or better) was leak tested by pressurizing with tank nitrogen. If no leaks were detected, the autoclave was evacuated. Pumping was continued for 15 minutes at the vapor pressure of water to ensure degassing. For the tests in supercritical water plus hydrogen, the same general procedure was followed. However, after leak testing, the evacuated bomb was filled with hydrogen.

After each exposure period, fresh water was added and the tests continued. The volume of water necessary to produce a pressure of 5000 psi at the test temperature was calculated from steam-table data. Normally, more water was added than the calculations showed to be necessary. The pressure was adjusted then at temperature by bleeding away the excess water.

In evaluating test data, weight-change rates, visual observation, and microscopic examination were used as the criteria for comparing the corrosion behavior of the materials.

Test Results

Each alloy was evaluated in degassed supercritical water at 1350, 1000 and 800 F at a pressure of 5000 psi. In general, a material having a weight change of less than 100 mg/dm²/130 days and showing a tarnish film or thin oxide layer was considered satisfactory. The less resistant alloys exhibited heavy oxide coatings and weight gains in excess of 100 mg/dm² or severe localized attack.

Tests at 1350 F

The results of the studies conducted in degassed supercritical water at 1350 F and 5000 psi are presented in Table 2 and shown graphically in Figure 3. The hardenable Armco 17-4PH alloy was found to be the most resistant, followed closely by Hastelloy F and Armco 17-7PH in that order. These alloys gained the least amount of weight (39, 52, and 64 mg/dm², respectively) and were covered with a thin

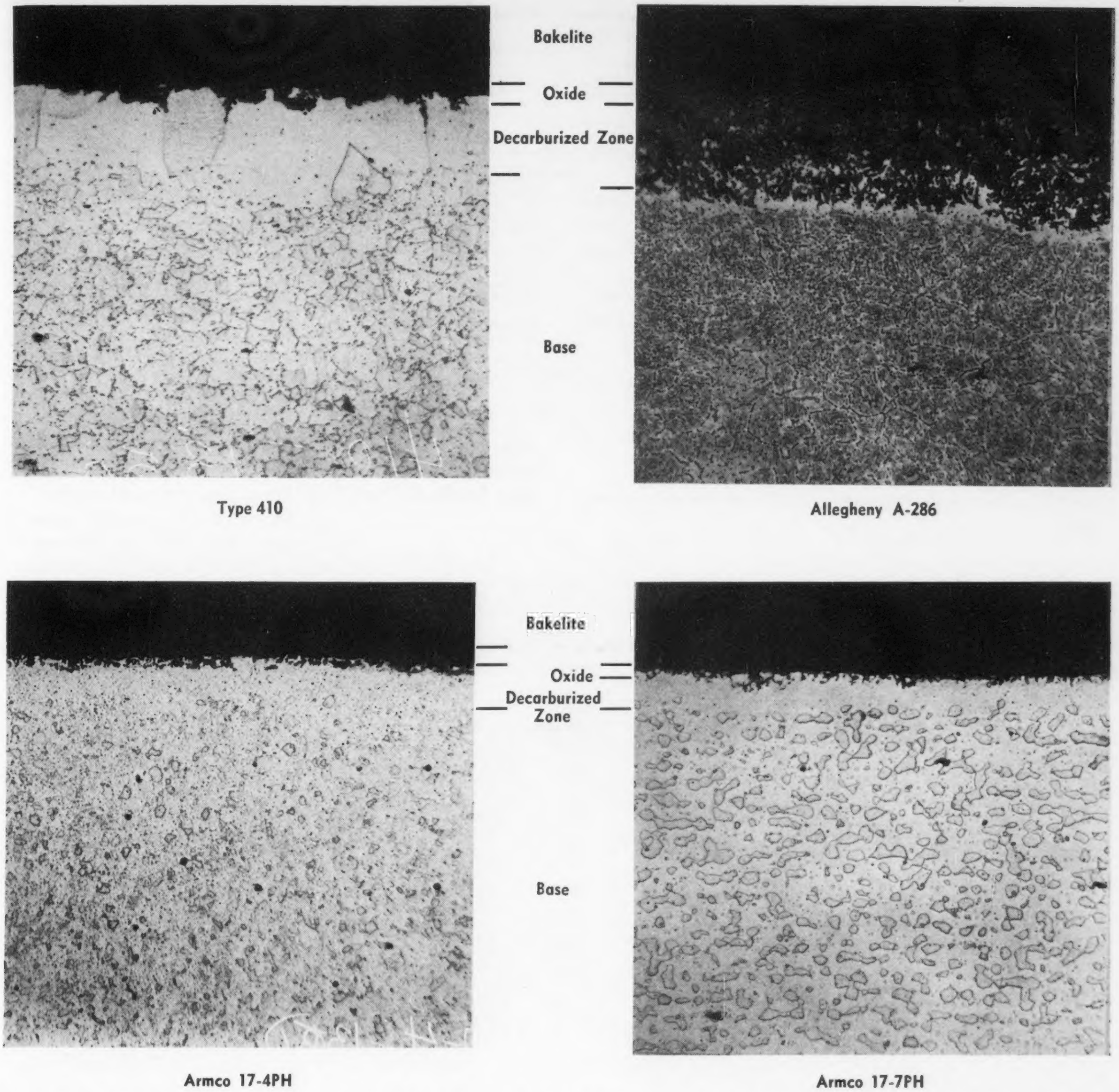


Figure 4—Photomicrographs of hardenable grades of stainless steel exposed 132 days to degassed supercritical water at 1350 F and 5000 psi. Etchant: modified aqua regia, 250X.

adherent oxide coating after 132 days of exposure. High weight gains (146 to 1152 mg/dm^2) and loose, heavy oxide coatings were observed for the Allegheny A-286, AMS 5616, Inconel X, Hastelloy X, and Types 302 and 410 stainless steel after a similar test period. Alloys exhibiting moderate weight gains (83 to 89 mg/dm^2) included the austenitic Types 347, 309, and 310 stainless steels.

It should be pointed out that although a few of the alloys exhibit a heavy scale, which might be expected to interfere with normal heat-transfer processes, the 132-day exposure in supercritical water did not result in any serious loss in section.

Assuming the scale composition to be essentially Fe_3O_4, an approximation of the penetration rate was calculated for all materials except Inconel X, Hastelloy F, and Hastelloy X. These three materials are not iron-base alloys and would have a more complex scale. These rates are contained in Table 2. With the exception of AMS 5616, Allegheny A-286, and Type 302 stainless steel, all rates are less than 1 mil/year, which, from the standpoint of loss in strength, is very low. Rates for the AMS 516, Allegheny A-286, and Type 302 were 65.6, 4.1, and 2.1 mils/year, respectively.

In general, the alloys corroded at a constant rate, although several materials, particularly the Armco alloys and Hastelloy F, exhibited most of their weight change in the initial exposure period and changed very little during additional exposure.

After exposure, the test specimens were examined under the microscope. Photomicrographs of these

TABLE 1—Heat Treatments and Typical Analyses for Test Materials

Test Material	Typical Analysis, Weight Percent	Heat Treatment
Type 410	0.15 C, 11.5-13.5 Cr, 1.0 Si, 1.0 Mn, bal Fe	1 hour 1750 F, oil quenched, plus 1 hour 1050 F
Type 302	0.08 C, 18 Cr, 8 Ni, 1.0 Si, 2.0 Mn, bal Fe	Quench annealed from 2000 F
Type 347	0.08 C, 17-19 Cr, 9-12 Ni, 1 Si, 2 Mn, Nb 10 x C (min), bal Fe	Quench annealed from 2000 F
Type 309	0.20 C, 22-24 Cr, 12-15 Ni, 2 Mn, 1 Si, bal Fe	Quench annealed from 2000 F
Type 310	0.25 C, 24-26 Cr, 19-22 Ni, 2 Mn, 1 Si, bal Fe	Quench annealed from 2000 F
Armco 17-4PH	0.05 C, 16.5 Cr, 4.0 Ni, 4.0 Cu, bal Fe	Solution heated 1400 F, aged 1 hour 900 F
Armco 17-7PH	0.07 C, 17 Cr, 7.0 Ni, 1.0 Al, bal. Fe	Solution heated 1400 F, aged 1 hour 900 F
Allegheny A-286	16 Cr, 26 Ni, 1-6 Ti, 0.26 V, 0.14 Al bal Fe	Solution heated 1800 F, aged 8 hour 1350 F
Inconel X	0.04 C, 15 Cr, 73 Ni, 0.7 Al, 2.5 Ti, 1.0 Nb, 0.5 Mn, 0.4 Si, 7.0 Fe	None (used as received)
Hastelloy F	0.15 C, 22 Cr, 45 Ni, 6 Mo, 2 Nb, 2 Ti, 1.0 Mn, 1.0 Si, bal Fe	None (used as received)
Hastelloy X	0.15 C, 22 Cr, 45 Ni, 9 Mo, 1.0 Mn, 1.0 Si, bal Fe	None (used as received)
AMS 5616	12 Cr, 2 Ni, 3 W, bal Fe	None (used as received)

TABLE 2—Stainless Alloys Exposed to Degassed Supercritical Water at 1350 F and 5000 Psi

MATERIAL	Weight Gain, mg/dm², After Indicated Exposure, Days							Penetration[1], mils/year	Remarks
	14	30	60	90	104	118	132		
Type 410	35	59	94	129	139	147	175	0.62	Dark coating
AMS 5616	1950	....	....	....	....	....	....	65.6	Heavy dark coating
Type 302	116	187	334	400	403	386	404	2.1	Loose dark coating
Type 347	36	55	56	75	76	73	83	0.3	Dark film plus scattered shiny black spots
Type 309	49	56	64	72	87	76	83	0.3	Dark film plus scattered shiny black spots
Type 310	28	46	57	78	68	75	86	0.3	Dark film plus scattered shiny black spots
Armco 17-4PH	36	36	31	31	35	34	39	0.14	Dark film
Armco 17-7PH	41	49	58	56	59	58	64	0.23	Dark film
Allegheny A-286	340	622	872	1032	1073	1103	1152	4.1	Heavy dark coating
Inconel X	....	241	403	321	323	....	....	....	Heavy dark coating, flaking at 75 days
Hastelloy F	32	38	42	42	49	43	52	....	Dark film
Hastelloy X	32	112	151	161	148	149	148	....	Loose dark coating

[1] Calculations based on an assumed Fe_3O_4 scale.

TABLE 3—Stainless Alloys Exposed to Degassed Supercritical Water at 1000 F and 5000 Psi

MATERIAL	Weight Gain, mg/dm², After Indicated Exposure, Days										Penetration[1], mils/year	Remarks
	7	14	21	28	42	58	87	108	130	148		
Type 410	11	12	..	16	..	16	11	11	12	10	0.032	Dark tranish film; scattered rust spots
Type 302	19	28	..	42	..	65	76	82	93	96	0.30	Dark coating
Type 347	8	8	..	12	..	15	12	9	12	9	0.031	Dark tranish film
Type 309	10	10	..	10	..	17	15	13	14	13	0.032	Dark tarnish film
Type 310	3	3	..	5	..	10	5	4	6	5	0.017	Dark tarnish film
Armco 17-7PH	1	0	..	0	..	4	0	0	4	0	....	Dark tarnish film
Allegheny A-286	3	15	..	41	..	95	124	144	171	183	0.59	Dark coating
Inconel X	..	..	..	77	..	92	..	104	107	..	....	Dark coating
Hastelloy F	..	..	4	..	13	13	..	..	..	..	....	Dark tarnish film
Hastelloy X	..	..	9	..	19	18	..	..	..	..	....	Dark tarnish film
AMS 5616	..	..	..	17	..	19	..	..	..	..	0.16	Dark tarnish film

[1] Calculations based on an assumed Fe_3O_4 scale.

TABLE 4—Stainless Alloys Exposed to Degassed Supercritical Water Plus Hydrogen at 1000 F and 5000 Psi

MATERIAL	Weight Gain mg/dm², After Indicated Exposure, Days					Penetration[1], mils/year	Remarks
	14	28	58	87	108		
Type 410	10	10	2	3	2	0.009	Dark tarnish film
Type 302	32	44	64	74	87	0.39	Dark coating
Type 347	16	11	21	20	21	0.095	Dark tarnish film
Type 309	16	6	..	..	..	....	Dark tarnish film
Type 310	6	5	8	6	8	0.036	Dark tarnish film
Armco 17-4PH	7	7	4	0	1	0.005	Dark tranish film
Armco 17-7PH	3	3	6	11	5	0.022	Dark tarnish film
Allegheny A-286	8	5	2	2	9	0.04	Dark tarnish film
Inconel X	80	68	54	47	51	....	Dark coating
Hastelloy F	4	0	0	4	5	....	Dark tarnish film
Hastelloy X	39	44	54	71	78	....	Dark coating

[1] Calculations based on an assumed Fe_3O_4 scale.

samples are presented in Figures 4 through 6. It will be noted that for the most part the attack at 1350 F was localized and selective. Only the Hastelloy F material exhibited general attack. However, for the hardenable Armco alloys the selective penetration along grain boundaries was superficial. The Type 347 stainless steel, which evinced only a moderate weight change, was found to be deeply pitted. Light to moderate pitting was also noted for the Type 309 stainless steel. The Allegheny A-286, Inconel X, Hastelloy X, and Type 302 stainless steel were severely corroded, exhibiting selective attack in addition to a heavy scale.

The metallographic examination also revealed a decarburized zone adjacent to the layer of corrosion product. Thickness of the zone ranged from about 4 mils for the Type 410 stainless steel and Inconel X to less than ½ mil for the Hastelloy F material. Aside from the decarburization, structural changes were normal for alloys of these types subjected to prolonged heating at 1350 F. The scale on the iron-base alloys was magnetic, indicating the presence of Fe_3O_4.

Tests at 1000 F

More of the materials were resistant to degassed supercritical water at 1000 F and 5000 psi than were resistant at 1350 F and 5000 psi (see Table 3 and Figure 7). The hardenable A-286, Type 302 stainless steel, and nickel-base Inconel X are the most rapidly attacked, exhibiting weight gains of 100 mg/dm² or more after from 130 to 148 days' exposure. Type 410 stainless steel and Hastelloy X, which like the above alloys suffered

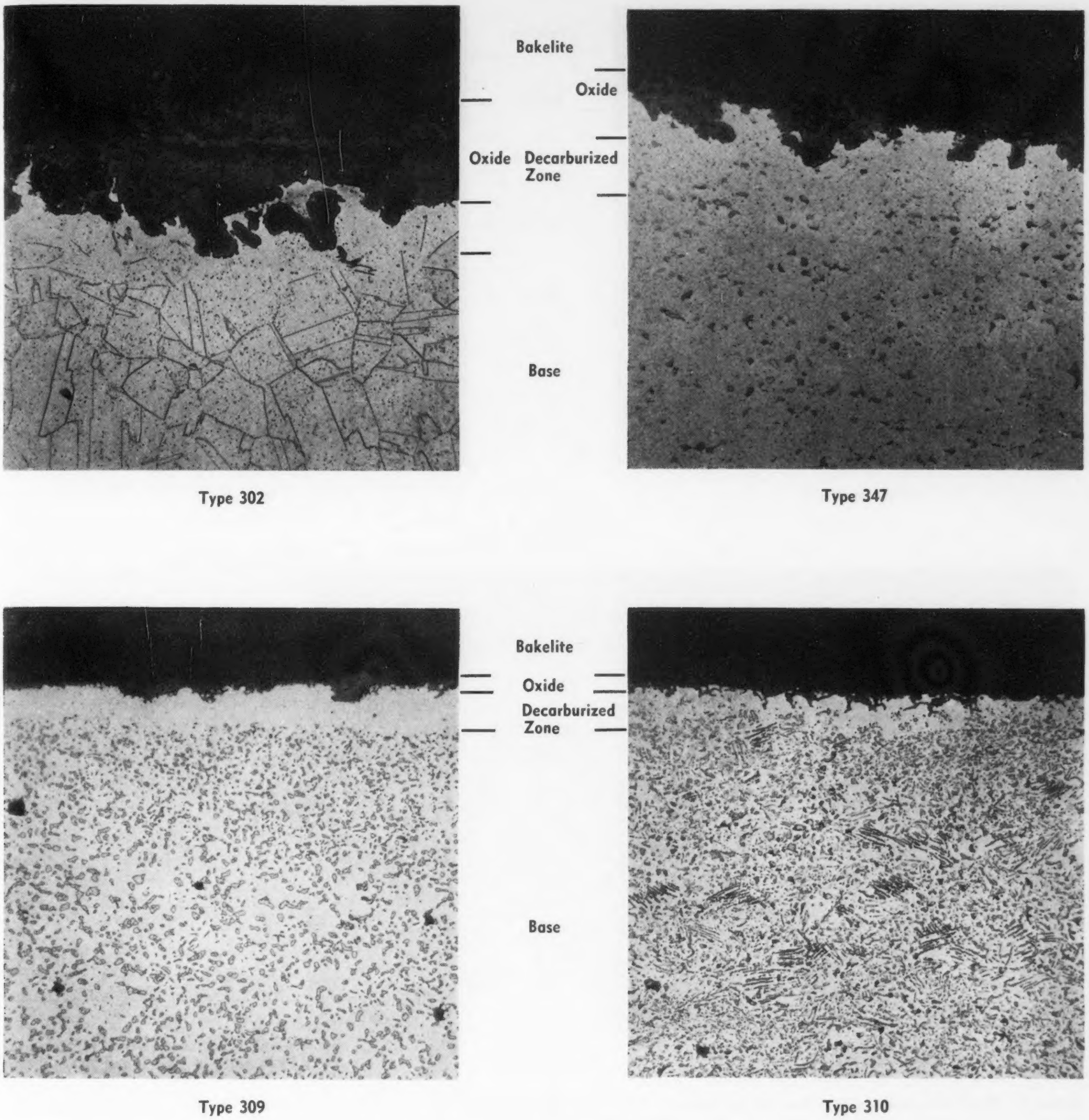


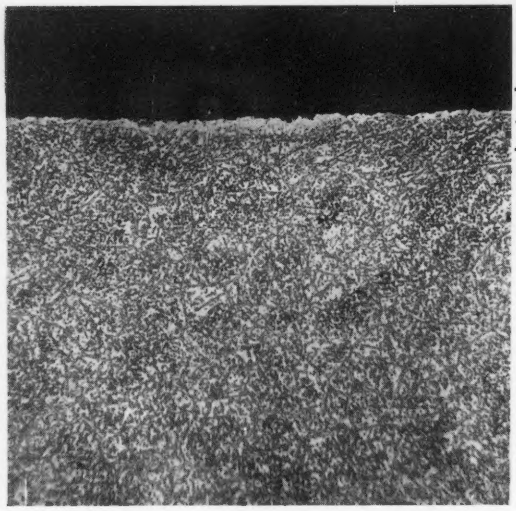
Figure 5—Photomicrographs of stainless steels exposed 132 days to degassed supercritical water at 1350 F and 5000 psi. Etchant: modified aqua regia. 250X.

severe corrosion at 1350 F, are among the most resistant materials (weight gains less than 20 mg/dm² after from 58 to 148 days) to 1000 F supercritical water. Equally good corrosion properties were noted for Types 309, 310, and 347 stainless steels, Armco 17-7PH, Hastelloy F, and AMS 5616. The latter alloys exhibit a tarnish film and low weight gains ranging from 5 to 13 mg/dm².

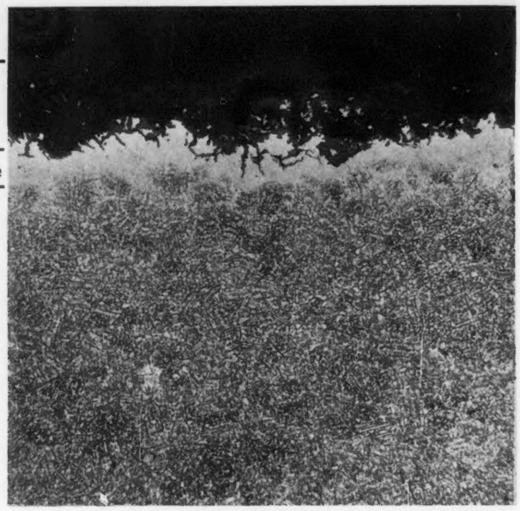
Calculated penetration rates (assuming scale composition to be Fe_3O_4) for many of the materials are included in Table 3. It can be seen from these data that rates were less than 1 mil/year.

A metallographic examination of the specimens revealed that only in the case of the Inconel X did corrosion penetrate along grain boundaries. The Type 302 stainless steel exhibited pitting attack, whereas the other compositions show only light uniform general attack (see photomicrographs, Figures 8 through 10). None of the alloys suffered decarburization or significant changes in microstructure.

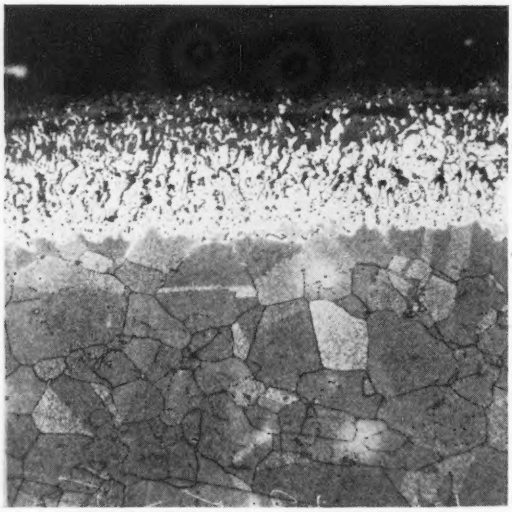
In another test at 1000 F, a duplicate set of samples was exposed to supercritical water plus hydrogen. Weight-gain data and calculated penetration rates for this test are contained in Table 4. Examination



Hastelloy F



Hastelloy X



Inconel X

Figure 6—Photomicrographs of stainless alloys exposed 132 days (104 days for Inconel X) to degassed supercritical water at 1350 F and 5000 psi. Etchant: modified aqua regia, 250X.

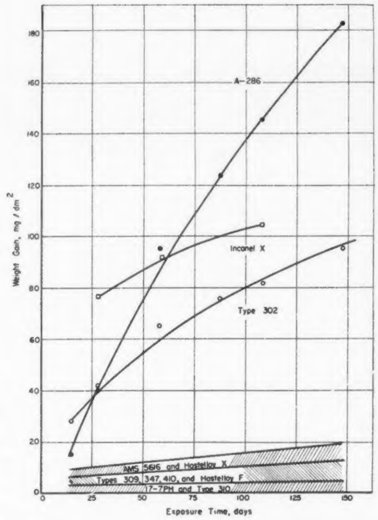


Figure 7—Corrosion of stainless alloys in supercritical water at 1000 F and 5000 psi.

of the data contained in Tables 3 and 4 shows that during an exposure of 108 days the Allegheny A-286 alloy was the only material exhibiting a significant reduction in corrosion rate in the presence of hydrogen. In degassed supercritical water, the weight gain was 144 mg/dm^2/108 days; in supercritical water plus hydrogen, the weight gain was 9 mg/dm^2/108 days. The other alloys, with the exception of Hastelloy X, behave essentially in the same manner as they did in the absence of hydrogen. In the presence of hydrogen, however, Hastelloy X is considerably less resistant. The reason for the observed differences in behavior of the Hastelloy X and Allegheny A-286 under the two test conditions at 1000 F is not apparent at this time.

Tests at 800 F

Corrosion data (weight-gain and calculated penetration rates) are presented in Table 5 for the stainless steel samples exposed 82 days to 800 F degassed supercritical water. Lowering the temperature 200 F resulted in lowering the corrosion rates for all materials. The attack was limited to a tarnish film, with weight gains ranging from 1 to 10 mg/dm^2 and penetration rates lower than a 0.10 mil/year. Extended exposure times would be necessary to establish which alloy or alloys are the most resistant.

Because of the excellent appearance of the samples and insignificant weight changes a microscopic examination was not conducted on the test specimens.

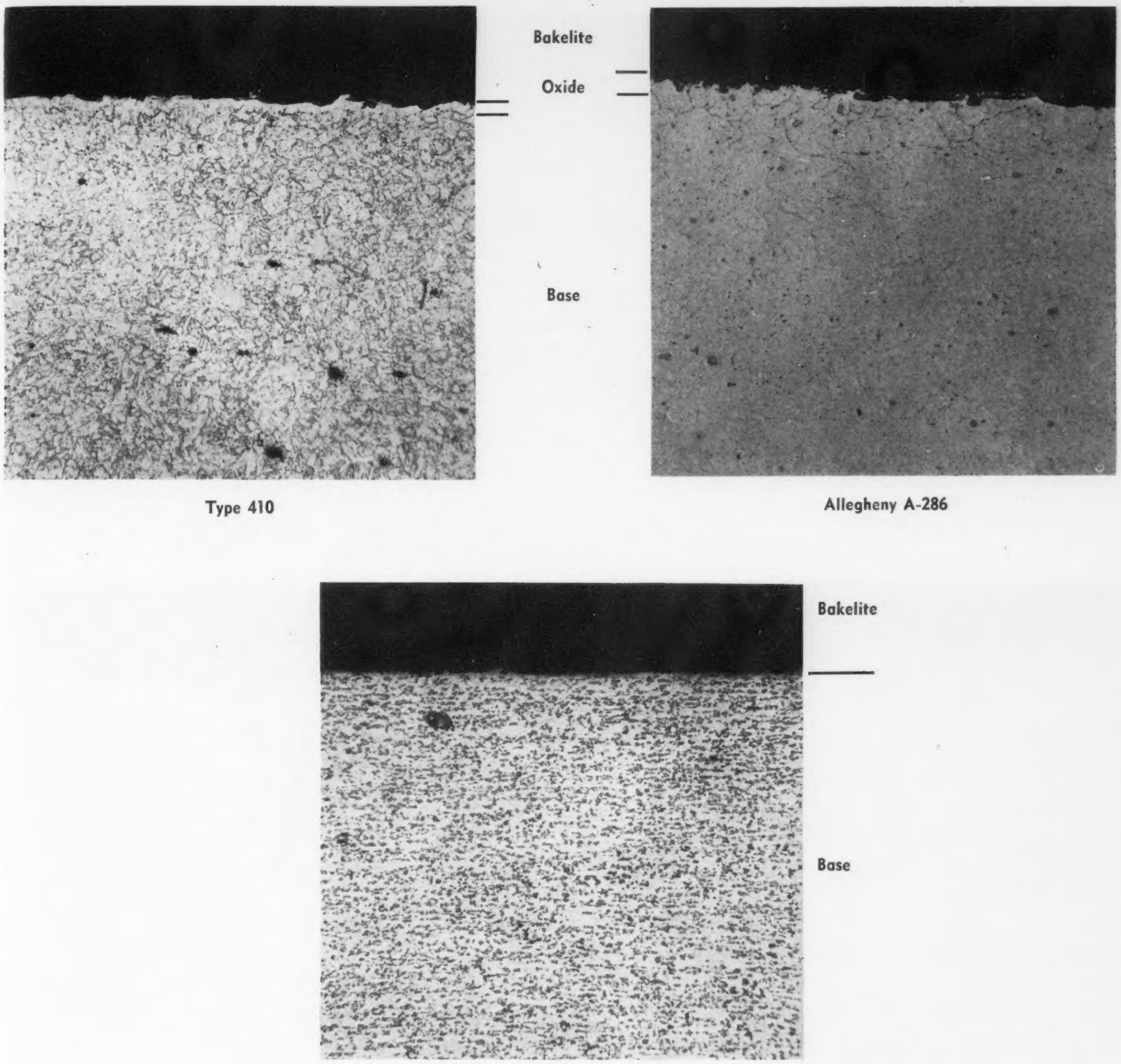


Figure 8—Photomicrographs of hardenable grades of stainless steel exposed 148 days to degassed supercritical water at 1000 F and 5000 psi. Etchant: modified aqua regia, 250X.

TABLE 5—Stainless Alloys Exposed to Degassed Supercritical Water at 800 F and 5000 Psi

MATERIAL	Weight Gain mg/dm², After Indicated Exposure, Days				Penetration[1], mils/year	Remarks
	14	28	54	82		
Type 410	5	9	4	10	0.055	Tarnish film
AMS 5616	..	8	11	..	0.097	Tarnish film
Type 302	1	1	3	8	0.044	Tarnish film
Type 347	3	0	1	1	0.0055	Tarnish film
Type 309	3	1	0	6	0.033	Tarnish film
Type 310	2	5	4	9	0.050	Tarnish film
Armco 17-4PH	2	0	0	8	0.044	Tarnish film
Armco 17-7PH	2	0	1	4	0.022	Tarnish film
Allegheny A-286	1	4	3	6	0.033	Tarnish film
Inconel X	3	2	2	1	....	Tarnish film
Hastelloy F	2	1	1	1	....	Tarnish film
Hastelloy X	2	1	1	2	....	Tarnish film

[1] Calculations based on an assumed Fe_3O_4 scale.

Effect of Stress

While this investigation was concerned primarily with corrosion properties in the absence of applied stress, a few tests were conducted to determine the effect of stress. Types 316 and 347 stainless steel samples under a constant stress of 90 percent of stress necessary to cause rupture in 1000 hours (15,000 and 12,000 psi, respectively) at test temperature were exposed in degassed supercritical water at 1350 F. After one week's exposure, the Type 316 stainless steel exhibited failure, while the Type 347 material was intact at the end of the month. Examination of the Type 316 revealed many fine cracks in addition to the main fracture. The cracks were primarily transgranular (see Figure 11) and appeared generally to be associated with a small corrosion pit.

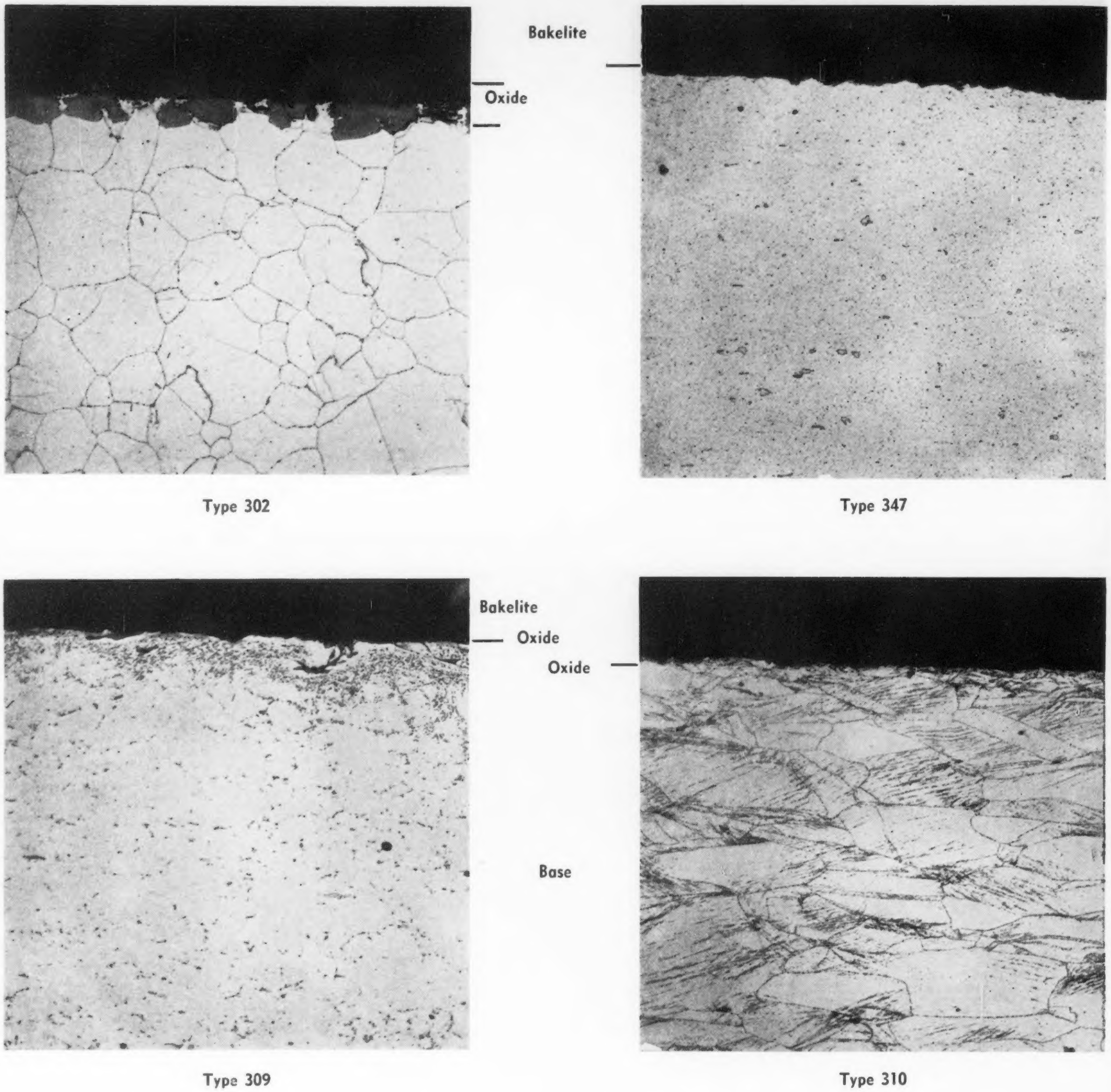


Figure 9—Photomicrographs of stainless steels exposed 148 days to degassed supercritical water at 1000 F and 5000 psi. Etchant: modified aqua regia, 250X.

Failures of this type also were observed for several of the sections of Type 316 stainless steel high-pressure tubing attached to the autoclave head, after extended (five months) exposure to degassed supercritical water at 1000 F.

Kinetics of Reaction

In general the weight-gain data suggest that corrosion of the stainless alloys in supercritical water most nearly follows a linear rate law. However, it should be pointed out that the nature of the data precludes precise interpretation. Values of rate constants calculated using the formula $w = kt$, where w is the weight gain in mg/dm^2, t is the exposure time, and k is the linear rate constant, are presented in Table 6. An Arrhenius-type plot of the log of the rate constant versus 1/T for several of the alloys is shown in Figure 12. The relationship between log of rate constant and 1/T was a straight line for the Type 302 stainless steel. For the other materials, three of which are shown in Figure 12, changes in slope with temperature were evident. Although the data at 800 F are based on relatively short exposure times, the lack of a constant slope suggests a possible change in mechanism with changes in temperature.

Discussion of Results

While it is recognized that the laboratory static test data reported herein may not be directly applicable to service life expectancy, evidence has been

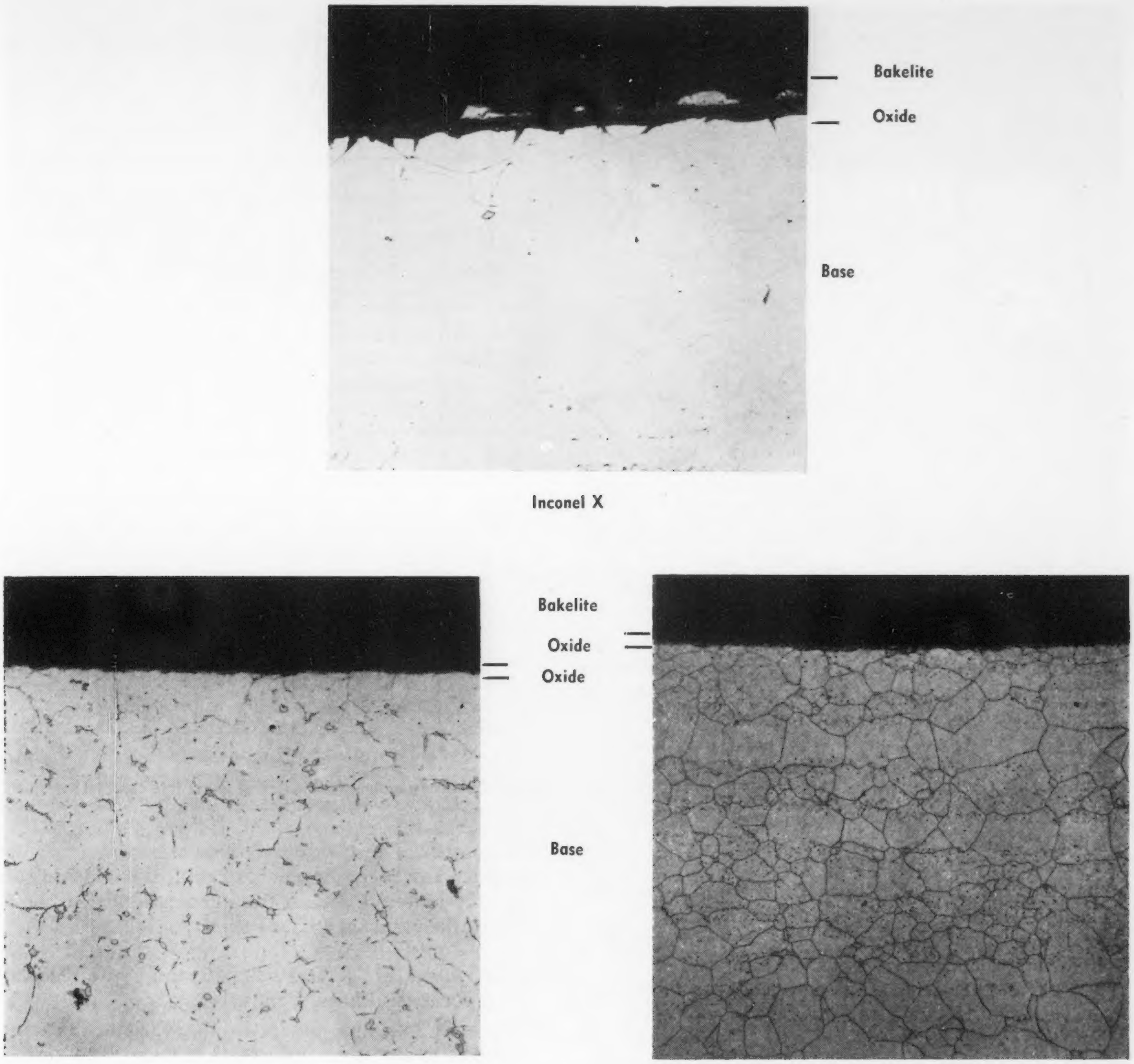


Figure 10—Photomicrographs of stainless alloys exposed 58 days (148 days for Inconel X) to degassed supercritical water at 1000 F and 5000 psi. Etchant: modified aqua regia, 250X.

TABLE 6—Rate Constants for the Corrosion of Stainless Alloys in Supercritical Water

MATERIAL	Rate Constant (k), mg/dm²/day for Indicated Test Temperatures		
	800 F	1000 F	1350 F
Type 410	0.05	0.10	1.2
AMS 5616	0.2	0.3	1.39
Type 302	0.10	0.66	4.7
Type 347	0.01	0.26	9.83
Type 309	0.073	0.29	0.83
Type 310	0.11	0.17	0.87
Armco 17-4PH	0.1	....	0.3
Armco 17-7PH	0.033	0.067	0.48
Allegheny A-286	0.07	0.18	9.3
Inconel X	0.011	0.97	6.7
Hastelloy F	0.011	0.22	0.39
Hastelloy X	0.024	0.31	1.8

given that Hastelloy F and the hardenable Armco 17-4PH and 17-7PH alloys are the most likely to give adequate service in degassed supercritical water at 1350 F. As the temperature is lowered to 1000 F and 800 F, the choice of materials is considerably greater. At 1000 F, only the Allegheny A-286, Inconel X, and Type 302 stainless steel were seriously attacked by degassed water. All compositions studied appear to offer acceptable corrosion behavior at 800 F.

The attack at 1350 F, as revealed by metallographic examination, was localized and selective. This was true even for the majority of materials considered to have good corrosion resistance. Some decarburization also was noted for the alloys tested at 1350 F. At 1000 F and below, the corrosion is more uniform.

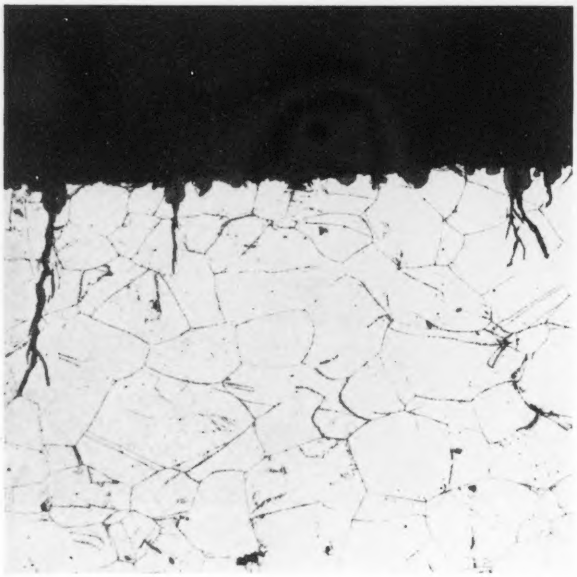


Figure 11—Photomicrograph showing fine crack in Type 316 stainless steel exposed to degassed supercritical water at 1350 F. 250X.

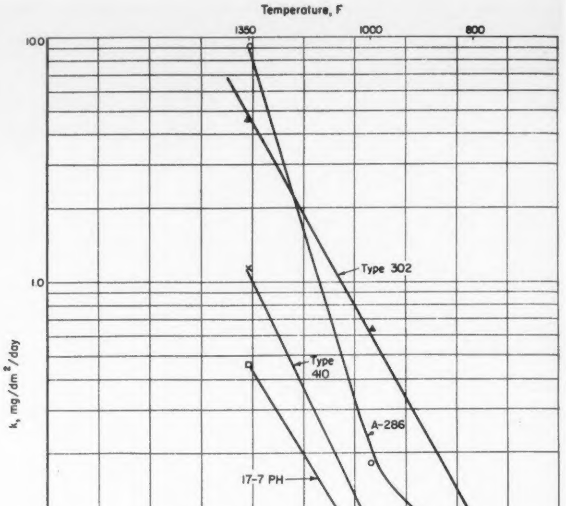


Figure 12—Temperature dependence of linear rate constant for several types of stainless steels.

When the stainless steels are exposed under stress to degassed supercritical water the possibility of stress corrosion cracking must be considered.

Acknowledgment

The work described in this paper was prepared under AEC Contract No. W-7405-eng 92.

DISCUSSION

Questions by Dr. Mortimer C. Bloom, Naval Research Laboratories, Washington, D. C.:

1. Have measurements of water conductivity under these conditions been made?
2. Was there any evidence of galvanic effects?

Reply by W. K. Boyd:

1. No attempt was made to measure water conductivity at the test temperatures.
2. No evidence of galvanic effects was observed for any of the test specimens.

Question by Craig Fong Cheng, General Electric Company, Schenectady, New York:

I would like to know what is the condition of the Inconel-X? Is it age-hardened?

Reply by W. K. Boyd:

The Inconel X material was tested as received in sheet form. The condition of heat treatment is not known. However, the microstructure would indicate that the material was in the quench-annealed condition, rather than age hardened.

Question by D. J. DePaul, Westinghouse Electric Corporation, Large, Pennsylvania:

Corrosion data are given on the various materials studied; however no information was given on the pressure vessel material in which these tests were conducted. Is there any information on the Timken alloy 16-25-6 which was employed for the containers?

Reply by W. K. Boyd:

The corrosion rate of Timken 16-25-6 alloy was not determined. However, the inside of the pressure vessel is in excellent shape, showing only a light-black oxide film after approximately one year of service in supercritical water at temperatures up to 1350 F.

Any discussions of this article not published above will appear in the December, 1957 issue.

Control of Corrosion with Zinc Coatings*

By J. L. KIMBERLEY

Introduction

ZINC IS an essential material of industry whose importance is sometimes underestimated. It is hoped that this paper will in part correct that situation. The subject—"Control of Corrosion with Zinc Coatings" covers a major usage which consumes more than 40 percent of the total new zinc available annually in the United States.

History

The following historical facts are of significance as related to the development and use of zinc coatings to extend the useful life of steel.

In 1742 a French chemist, Malouin, described a method for protecting steel by immersion in molten zinc. The process however was not applied industrially until 1837 when a British patent for fluxing steel with ammonium chloride prior to galvanizing was introduced. From this date the growth of industrial plants was rapid in Europe although early in the 20th century leadership in the industry, especially in plant development, passed to the United States.

It is to be noted that the commercial success of hot dip galvanized coats did not come about until a proper chemical flux had been discovered and developed to usefulness.

The first zinc made in the United States was produced about 1838 in a government arsenal and undoubtedly was used for galvanizing. In 1859 the first successful commercial retort plant of the Belgian type was erected at Butler, Pennsylvania.

Figure 1 shows the quantity of zinc used in galvanizing. Note the strong upward trend in total consumption of slab for galvanizing since the depression year of 1932. Notice that sheet and strip, a product of the steel mill's galvanizing facilities, is the largest consumer. Next are "others" and tube and pipe. The galvanizing of wire and wire rope consumes a very substantial portion of new slab zinc. Fittings, taking 10,000 tons a year, are also significant since this is still about 1 percent of the total slab zinc available.

For the year 1955, galvanizing will prove to have consumed approximately 430,000 tons of zinc for coating steel. Paint of all types will have taken over 60,000 tons, although this is in the form of zinc dust and zinc oxide produced largely from zinc ores and not included in the slab totals shown in Figure 1. Electrogalvanizing will take perhaps 20,000 tons; sherardizing and metallizing something less than 3,000 tons each.

★ Submitted for publication April 6, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

J. L. KIMBERLEY is executive vice-president and secretary of the American Zinc Institute, New York, N. Y. From 1944 to 1955 he was sales manager of Continuous Cast Alloy Division of American Smelting & Refining Co. His other experience includes service on the War Production Board, and in the U. S. Navy and work as a metallurgist with Scovill Manufacturing Co., Waterbury, Conn. He has a BS in mechanical engineering from Yale (1928) and an MS in metallurgy (1930).

Abstract

A history of the uses of metallic zinc and zinc coatings to control corrosion is outlined briefly with some consideration being given to the theory under which zinc is protective to steel. The following methods of application of zinc are discussed in detail: hot dip, metallizing, sherardizing and painting. The relative merits and weaknesses of zinc coats are considered with case histories being cited to show the fields of usefulness of such coatings. **5.3.2**

Dual Function of Zinc Coats on Steel

Zinc coatings derive their usefulness from the dual nature of their ability to protect steel. They are used primarily for exposures to the atmosphere whether outdoors or indoors. Zinc's first function is to prevent the rusting of steel by preventing contact of corrosive atmospheres. It acts first as a barrier, and in this respect is very effective.

Although zinc lies high in the galvanic series and has the ability to protect cathodically, it also has the virtue of forming complex and durable films on its surface which are resistant to corrosion in themselves, but not insulating to the electrical currents involved in sacrificial action. In this respect it is unique among those materials commercially and largely used for coatings.

Table 1 shows comparative weight losses of zinc and iron at Kure Beach (marine) and Middletown, Ohio (rural-industrial) over an eight-year period. Acting as a barrier, zinc would appear to be from 6 to 50 times more resistant than this particular steel depending on conditions of exposure. Such a tabulation is useful only as a guide and for discussing generalities. No indication of tendency to pit is presented. There is reason to feel that such a criterion would prove to be even more favorable to zinc.

Table 2 shows the penetration of corrosion into zinc and zinc-coated steel in inches per year at

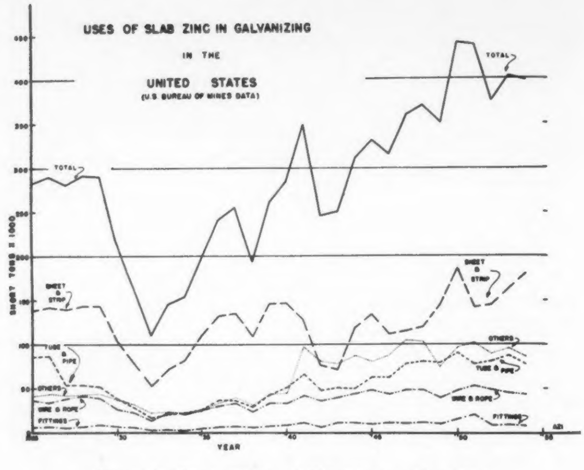


Figure 1—Consumption of slab zinc in galvanizing.

TABLE 1—Comparative Weight Losses of Zinc and Iron

	1 Year		2 Years		4 Years		8 Years	
Test Location	Low Cu Iron	Zinc	Low Cu Iron	Zinc	Low Cu Iron	Zinc	Low Cu Iron	Zinc
Kure Beach, N.C...	10	.85	21	1.3	42	1.8	108	2.2
Middletown, Ohio..	8	0.7	13	1.1	17	2.0	25	4

Weight losses are approximate; Unit of loss is grams per 4-inch by 6-inch specimen.

Palmerton, Pennsylvania (industrial, rural) and New York City (marine, industrial, urban). The rates are low.

Later in this paper additional information will be given regarding exposure test results on sheet zinc. Table 2 makes clear that it is reasonable to use such results on zinc alone as basis for estimating results on galvanized products.

After penetration and exposure of the steel base, zinc continues to give protection. This is because in the presence of moisture and when connected to steel, it establishes an electrical current which flows in such a direction that it will be expended sacrificially while protecting the steel.

In listing the strong features of zinc as a protective coat, over and above those already mentioned (namely basic resistance to atmospheric corrosion and the ability to protect sacrificially), there are many other characteristics which contribute to its usefulness. Except in times of national emergency when all metals are tight, it is freely available.

Zinc by itself is relatively inexpensive. Because of the fact that it melts at a low temperature and is readily fluxed, it can be conveniently applied to steel in controllable thin coats at low cost. It is readily produced in the form of oxide or dust for use in pigments, and as such in many applications exhibits at least partially the strong features of a full metallic coat both as a barrier and sacrificially. The product, as commonly used, has other virtues relating directly to its steel base, most important of which may be strength, fire resistance, and over-all economy.

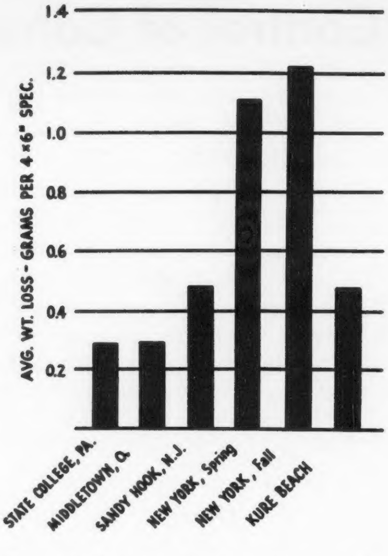


Figure 2—One-year weight losses on sheet zinc at various locations.[2, 3]

Test Exposure Variables

As mentioned, the greatest use of zinc-coated steel is for applications exposed to the atmosphere. It may be interesting to consider some of the factors involved in atmospheric corrosion, regardless of what materials may be involved. Even as weather conditions vary from place to place, the severity of atmospheric corrosion also varies, depending on local conditions of atmospheric pollution.

During the past few years, Committee B-3 of ASTM has collected weight loss data for samples of sheet zinc exposed in several locations for one year. Some of these data are shown in Figure 2. It will be seen that the New York City atmosphere is markedly corrosive, and that samples exposed in New York City in the fall corroded more than those exposed in the spring of the same year. Although it is not shown on the graph, there were great differences in rates of corrosion of samples exposed at Kure Beach, North Carolina, whether 80 or 800 feet from the ocean. Samples exposed in the 80 foot lot corroded approximately three times as fast as those in the 800 foot lot. It can be seen therefore that the location of test site has a pronounced influence on corrosion rates, and that time of year also may be of importance.

It is interesting to consider what happens when successive exposures of the same material are made in the same location. Since 1941 samples of *low-copper-iron* have been exposed annually for one-year periods at Kure Beach in the 800 foot lot and at Middletown, Ohio. These data are shown in Figure 3. It is evident that during the first five years corrosion at Kure Beach was much more severe than at Middletown. However, during the last five years this difference has been equalized and, at times, even reversed. Furthermore, note the greater variation in annual weight losses at Kure Beach than at Middletown.

Similar exposures have been made of *sheet zinc,* with

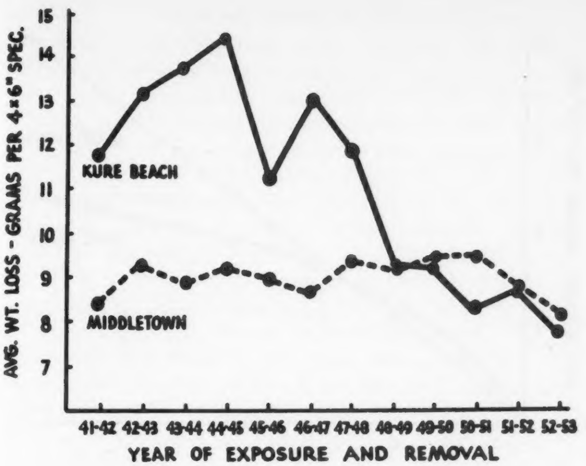


Figure 3—One-year weight losses on low-copper-iron.[2]

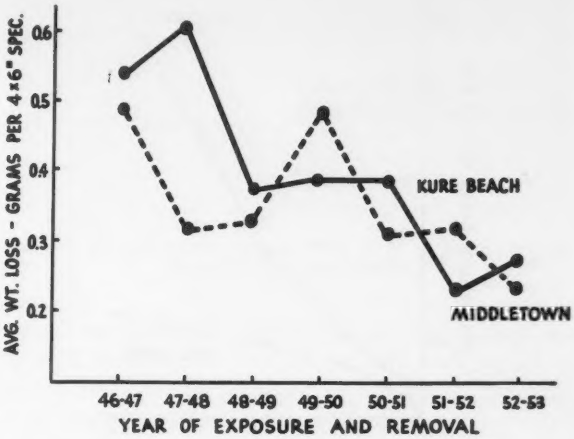


Figure 4—One-year weight losses on sheet zinc.[2]

results as shown in Figure 4. There is far less difference between the one-year weight losses of zinc than of iron. However, the zinc samples also show the trend toward lower corrosion rates at Kure Beach.

These data lead to a very obvious conclusion: It is not safe to predict the severity of an atmosphere from limited data.

The figures thus far have shown only the effect of one year's exposure in the various atmospheres. How do corrosion rates change with length of exposure? Figure 5 shows time-corrosion curves of a low-copper-iron, 0.04 percent Cu exposed at Middletown and Kure Beach. At Middletown the iron rust became protective and the corrosion rate decreased with time. At Kure Beach the opposite occurred. After the first year the corrosion rate actually accelerated. This acceleration was caused by moisture and contamination retained by the thick layer of rust on the underside of the specimens. Actually, much more than half of the total corrosion occurred on the underside where ocean salts could not be washed out of the rust by rain.

Time corrosion curves of sheet zinc exposed at Middletown and Kure Beach are shown in Figure 6. Note that at Middletown the zinc corrodes in proportion to time; that is, the eight-year weight loss is twice that at 4 years, four times that at 2 years, and 8 times that at one year. At Kure Beach, however, the corrosion products are protective and the corrosion rate decreases with time.

Influence of Coating Thickness

It already has been seen that zinc coatings corrode similarly to sheet zinc. Thus, doubling the thickness of a zinc coating would double its life in an atmosphere such as that at Middletown or in any other atmosphere that develops a linear corrosion rate for zinc. However, as seen in Figure 6, for a marine atmosphere such as Kure Beach, doubling the coating thickness would approximately triple the coating life.

Actual service and field tests have shown that heavy zinc coatings give steel excellent protection against rust for many years. This is evidenced in reports of the American Society for Testing Materials Committee A-5.

A general estimate of the protective value of zinc coatings is given in Table 3. The figures are based on exhaustive atmospheric exposure tests of a wide variety of products such as sheet, hardware, structural shapes and tubular goods. The estimates are described as reasonable values for the expected life of zinc-coated products. Of necessity, they are approximate or average.

It is clear that the heavier the zinc coating, the longer the life before rusting will start. Burns and Bradley[4] state that the life of zinc coatings indoors is roughly five times that outdoors in the same location. Abnormal conditions of alternate condensation and drying would, no doubt, have a large influence on any such generalization.

Interpretation of "Failure"

There are at least two schools of thought on what

TABLE 2—Penetration of Corrosion Into Zinc and Zinc-Coated Steel[1]

MATERIAL	Corrosion Penetration, Inches per Year: Palmerton, Pa.	Corrosion Penetration, Inches per Year: New York City
Rolled Zinc	.000064	.00028
Galvanized Iron	.000052	.00027

TABLE 3—Estimated Life of Zinc-Coated Products In the Atmosphere[1]

Thickness, In.	Weight in Oz./Sq. Ft. of Surface*	Life In Years Under Atmospheric Conditions: Rural	Tropical Marine	Temperate Marine	Suburban	Urban	Highly Industrial
.0036	2.00	50	40	35	30	25	15
.0023	1.25	35	30	25	20	17	9
.0018	1.00	25	20	15	12	10	7
.0011	0.60	10	8	7	5	4	3
.00066	0.37	7	6	5	4	3	2
.00044	0.25	5	4	3	3	2	1

* In the case of galvanized steel sheets the weight of zinc is specified in terms of total zinc on both sides of the sheet; i.e., a 2-ounce sheet has 1 ounce of zinc per sq ft of surface.

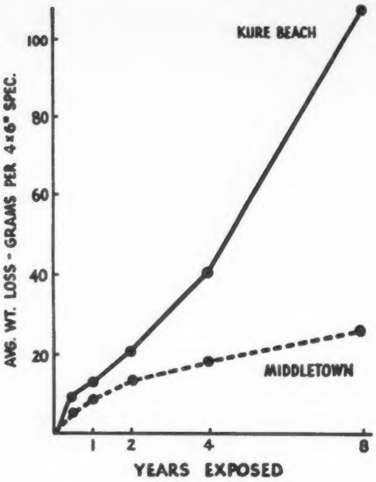


Figure 5—Extended exposures on low-copper-iron.[2]

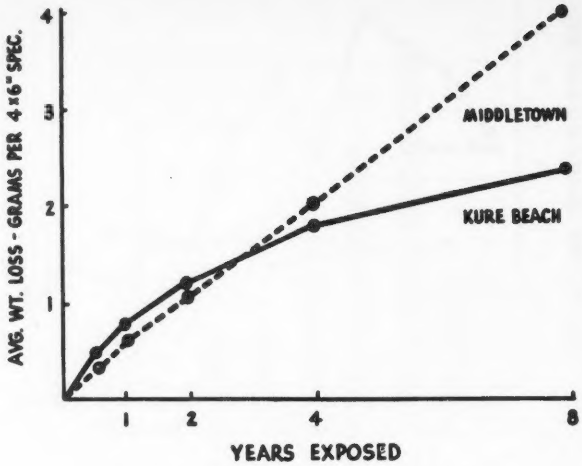


Figure 6—Extended exposures on sheet zinc.[2]

constitutes the failure of a zinc coat. There are those who feel that failure has occurred at the first visible evidence of rust. Certainly a rusted galvanized sheet is not attractive and so the position is understandable where appearance is of importance. However, this period of time, whatever it may be, is much shorter than the actual time of first penetration, which truly represents the useful lifetime of the product from a utilitarian point of view. It should be noted that the life of rusted galvanized sheet can be greatly extended with satisfactory appearance, by the application of zinc base paints after first rusting has taken place.

In conventional methods for hot dip galvanizing of steel, the coating from the steel surface to the outside of the zinc consists of several layers of iron-zinc alloy or compound which are richer in iron at the inner or steel surface, and vary to essentially pure zinc at the outside. During service, and as the pure zinc is corroded away, the iron-zinc layers become exposed and develop a reddish or pinkish corrosion product which is somewhat unsightly but is actually not rust of the base metal. The steel is still covered and completely protected. This also has led to misunderstanding. The truly proper time to paint is at the appearance of such "pre-iron rust-corrosion."

Problems

There are just no cure-alls for basic industrial problems. It is proper therefore to consider the difficulties as well as virtues involving zinc. In discussing the limitations of zinc, one must mention its relative inability to withstand satisfactorily, exposures which are strongly acid or strongly alkaline and also that it is not frequently used at temperatures above 450 F. Its susceptibility to acids and strong alkalies sometimes may make its application as a coat questionable in highly industrialized areas. In such cases both the detail of the exposure and the economics of specific situations should be considered—a more resistant material may be too costly.

Zinc-coated articles, if stored for significant periods of time under conditions which permit moisture to be trapped between closely adjacent surfaces, may be damaged by a form of corrosion known as "wet storage stain" or "white rust." The evidence of attack is normally a whitish powder on the surface and a loss of "spangle." If the powder wipes off readily no important damage has taken place. If heavy deposits are found which will not come off readily, the weakened area should be fortified as with zinc oxide-zinc dust paint.

The moisture which causes the trouble may form from condensation—as in moving from cold to hot, or hot to cold locations with humid atmospheres—or from exposure to the weather of sheets, coils, or manufactured articles while bundled.

Chromate or silicate dips may be used to prevent such action for moderate periods of time, but in any circumstance storage should be favorable—dry, and with individual pieces *definitely separated.* The surface films left on the galvanized product by some types of protective dips may interfere with the adherence of paint.

Galvanized hot water storage tanks are among the more common zinc-coated steel products. In many locations and probably in a majority of installations there is no better tank, when both cost and service life are properly evaluated.

Occasionally however, failures take place rapidly. In such cases multiple perforations will be in evidence, although the unperforated areas of the inside zinc coating will be found still in perfect condition. The term "buckshot corrosion" has been used to describe the problem.

Studies have revealed that the combination of: (1) dissolved oxygen, (2) temperatures above 140-150 F, and (3) bicarbonates or nitrates in the water tend to make the zinc cathodic with respect to the iron. Such a reversal of polarity is unlikely with oxygen-free water or if the water carries chlorides, sulfates, silicates or calcium which tend to preserve the anodic reaction of zinc.[5]

General Nature of Coat

As has been indicated earlier, molten zinc reacts with iron forming a series of zinc-iron alloys. Therefore, in conventional hot dip operations the total zinc coating will be found to be made up of several distinct layers of Fe-Zn compounds and alloys covered with a final layer of almost pure zinc. These iron-zinc alloys and compounds are brittle. This is why conventional hot dip coatings, though statically entirely adherent, are subject to cracking or flaking under severe bending or forming operations. It should be kept in mind that many hot dip coats are applied after forming and are not subject to deformation in service.

It has long been known that minor additions of aluminum (on the order of ¼ percent) to the zinc bath will suppress such iron-zinc reactions. However, in the conventional galvanizing process the difficulty of maintaining aluminum in the zinc bath in the presence of molten chloride fluxes has made its use impractical since the flux would quickly strip the aluminum from the bath.

The development of continuous coating methods which operate either without fluxes, or with short immersion periods and no flux on the bath surface, permits the use of aluminum in the zinc bath. The iron-zinc alloy formation is suppressed and the resultant essentially pure zinc coating will adhere even after severe forming and drawing. Typical differences in microstructure of the two coatings are shown in Figure 7. The several zinc-iron alloy layers are very evident in the conventional coating to the right, but almost entirely absent in the aluminum bearing coating to the left.

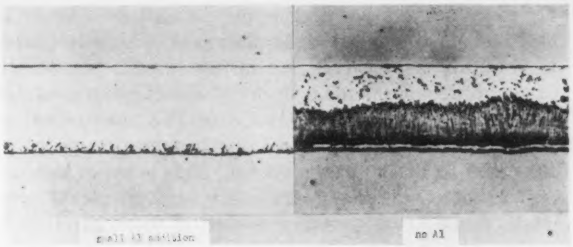


Figure 7—Photomicrograph showing effect of Al on Fe-Zn layers in coating of galvanized sheet.[2]

Methods of Application

Five basic methods for applying zinc coats will be discussed below.

Metallizing

Metallizing applies zinc to a surface by means of spraying. Pure zinc wire or powder is passed through a spray gun and melted in an oxyacetylene flame which is incorporated in the device. A jet of compressed air atomizes the molten metal, projecting the particles at high velocities onto the surface to be coated. The high velocity particles adhere to the surface of the steel and form a continuous film of controllable thickness. The surface must be chemically clean as accomplished by sandblasting when the metal is applied.

Metallizing has proven useful in coating such products as transformer cases, laundry baskets and processing equipment (i.e., degreasers and clay drying rolls). It finds broad application where hot dip galvanizing is not practical, as in inacessible areas.

Sherardizing

Sherardizing is applied to small parts such as nuts, bolts, washers, castings, and also on larger products such as conduit pipe. Parts are tightly packed with zinc dust in an air-tight container which is then revolved and heated to temperatures close to but below the melting point of the zinc. The zinc fuses to itself and diffuses onto and into the steel providing a thin and uniform corrosion-resistant coat. Sherardized products exhibit a rich gray texture and receive and retain paints, varnishes and enamels well. The coatings are ductile and controllable.

Pigment in Paints

Zinc is used as a pigment in paints in the United States to a very large extent, over 60,000 tons of zinc content per year being involved. By far the largest portion of this tonnage goes into zinc oxide used in combination with other oxides and materials for conventional house paint. This aspect of zinc usage will not be discussed here since it is not basically related to the protection of metal.

Two other basic types of zinc-bearing paint are of concern. One is a so-called metallic zinc paint, the pigment of which contains 80 percent zinc dust or zinc powder and 20 percent zinc oxide with suitable vehicles, and the other a zinc-rich paint containing about 95 percent zinc dust, again with suitable vehicle. These paints are used to protect steel and offer to a substantial extent the same type of protection as pure zinc coats (i.e., they function first as a barrier and then sacrificially when the barrier is broken). They are useful on their own when the products to be protected are not conveniently galvanized. They are useful to repair and extend the life of galvanized structures which have started to rust.

Both types are readily applied to any dry and firm surface, free from loose rust. These paints are not inexpensive when their cost is expressed in terms of dollars per gallon but justify themselves well when considered from the point of view of coverage and life expectancy.

Electrodeposition

Electrodeposition of zinc on steel has undergone significant developments in recent years. When applied continuously to strip steel the process is commonly referred to as electrogalvanizing. Applied to individual pieces in "batches" it is termed zinc electroplating.

In electrogalvanizing the zinc coating is also tightly bonded to the steel and has good adherence and ductility. Such coatings provide an excellent base for paint after a phosphate treatment such as bonderizing.

Electrogalvanized sheet steel is commonly pro-

duced in one of two grades on continuous lines: (1) a tenth of an ounce per square foot which is plated at about 325 to 350 feet per minute, or (2) two-tenths of an ounce per square foot which is plated at 150 to 175 feet per minute. Much of the sheet steel so galvanized is bonderized in the line as pretreatment for parts to be painted.

One of the major electrogalvanizing plants produces 8,000-9,000 tons per month of such product in coils weighing from 3 to 14 tons each. Such coated steel finds application either as base for paint and enamel in automotive and appliance service or "as produced" in exposures of minor severity, since the zinc coat is thin.

Hot Dip Galvanizing

Hot dip galvanizing is the most widely used method of applying zinc coatings to steel. Prior to coating with zinc in conventional operations the steel must be cleaned by pickling and given a flux coat. After being so cleaned (commonly with hydrochloric or sulfuric acid), rinsed, fluxed with zinc chloride or zinc ammonium chloride, and dried, the steel is immersed in a bath of molten zinc. There, under conditions of best practice, it is controlled with respect to composition and temperature and kept in the bath for varying periods, depending upon the mass of the part or parts to be coated. In general, the steel should reach the operating temperature (about 850 F) of the zinc bath and then be withdrawn. The natural pickup of zinc coat under such conditions is about four to five thousandths of an inch. The thickness is controlled in various manners including the regulation of bath temperature, time of immersion, steel surface condition, and by many mechanical means such as jarring, shaking, roll pressures and settings on sheet, charcoal wipes on wire, air blasts or superheated steam blasts on tubes and pipe.

Steel Wire

Steel wire has been galvanized by hot dip methods continuously for many years. The process is efficient and economical. The principles are the same as those involved in any other form of galvanizing. It was particularly interesting to learn that the strength of a steel bridge wire drawn and tempered to a tensile strength of 260,000 pounds per square inch dropped only to 245,000 pounds per square inch as it went through the galvanizing cycle. The permanence of galvanized steel wire is perhaps best demonstrated by the fact that the original galvanized steel cables still support the Brooklyn Bridge.

Steel Tubing and Pipe

Steel tubing and pipe is galvanized by a semicontinuous process. Again the operation follows conventional patterns, but is particularly interesting in that the control of thickness of the zinc coat is accomplished by blasts of air or superheated steam which remove any excess of zinc from outside and inside. Another unique feature of the process is the use of a magnetized roll which carries the tubing from the bath through air rings which control the outside coat and to the steam valve which blasts the excess from the inside.

Recent years have seen the development of *continuous line galvanizing equipment* for strip steel. There are 34 units now being operated in the United States, and five contemplated. This equipment presently represents well more than 75 percent of the steel industry's capacity for galvanizing sheet. Four million dollars is a good estimate of average line cost.

Continuous galvanizing lines are of two basic types. The first type feeds "hard temper" cold rolled sheet just as it comes from the rolling mill. The first operation carries this sheet from the coil through an oxidizing furnace which burns off the excess roll oil and uniformly oxidizes the surface. Then the sheet continuously passes through a long surface preparation and softening chamber. There in the presence of dissociated anhydrous ammonia, the oxide on the surface is gradually reduced and the sheet annealed until such time as (after a passage of several hundred feet) the softened strip enters the bath while still under the protection of a reducing atmosphere and is coated. Another long extension of the machine carries the galvanized strip through cooling, levelling, and cutting to length or coiling. The capacity of this type machine is limited by its ability to soften the sheet. Such capacity is currently on the order of one-quarter ton per inch of width per hour (i.e., on a 26-inch wide sheet about 6½ tons per hour). These lines run at speeds in the range of 90 to 120 feet per minute, depending on the gauge of the steel being coated.

The second type of continuous galvanizing line is fed coil stock which has been annealed "ahead of the line." In this case the travelling strip is cleaned, pickled, scrubbed, rinsed, fluxed and preheated prior to entry into the galvanizing bath. After galvanizing, the cycle is much the same as in the type which anneals "in the line." The factors which limit capacity on this type are the abilities to melt zinc and to preheat the strip prior to its entry into the bath. It is substantially faster, with operating speed on lighter gauge sheet in excess of 300 feet per minute.

Both types of machine have thoroughly justified themselves and the product which they make has proven of great benefit not only to the steel industry but to consumers. The coating is more uniform and more ductile. Many operations of drawing, forming and bending which previously were not practical on galvanized steel sheet are now the simplest of routine without rejection. In addition to the improvement of coat uniformity and the ability of the material to withstand severe deformation, its availability in the form of coil stock permits subsequent manufacturing operations on automatic equipment at greatly increased rates of production and with greatly reduced labor costs. Galvanized sheet produced in 1955 came close to 2,900,000 tons. More than half of this was from continuous lines. It is felt that the continuous line product, because of its superior ductility, opens great new avenues of usage for galvanized steel.

References

1. Zinc Metals and Alloys. The New Jersey Zinc Company, 1949.
2. O. W. Ellis, Armco Steel Corp. Paper before American Zinc Inst. Annual Meeting, Chicago, Apr. 1955.
3. Report of Committee B-3, Proceedings ASTM, **53**, 194 (1953).
4. Burns and Bradley. Protective Coatings for Metals. American Chemical Society Monograph Series No. 129, Reinhold Publishing Corp., New York, N. Y.
5. Hoxeng and Prutton. Electrochemical Behaviour of Zinc and Steel in Aqueous Media. *Corrosion*, **5**, No. 10, 330-338 (1949) Oct.

DISCUSSION

Comments by Charles W. Ambler, East St. Louis, Illinois:

There is one very important matter we should always keep in mind to help prevent corrosion of galvanized hot water boilers. C. C. McKee found that a concentration of 1 ppm of copper sulfate in a cooling system caused the removal of the galvanizing from pipes in as short a time as two months. Present day plumbing practice is to use copper water service pipes. L. Kenworthy found that the rate of corrosion of galvanized iron or zinc is materially increased by the presence of traces of copper in water. As little as 0.1 ppm of copper causes a definite increase in corrosion rate. With amounts of copper up to 0.3 ppm the degree of corrosion is proportional as to the amount of copper. The copper appears to deposit as small metallic particles on the surface of the zinc. Galvanic cells then form, with the copper particles as cathodes and the zinc and iron surfaces as the anodes. With many natural waters, sufficient copper is dissolved by the simple passage of water through copper pipes to affect the rate of corrosion of galvanizing but not a sufficient amount to cause a noticeable loss from the copper pipes. The deleterious effect on galvanizing of soluble copper in water may be mitigated by placing a copper trap just ahead of the galvanized system. This trap consists of granulated zinc through which the water must pass. Pertinent references are C. C. McKee, *Power Plant Engr.*, **36,** 658 (1943); L. Kenworthy, *Inst. Met.*, **69,** (Part II), 67 (1943).

Comments by E. A. Anderson, New Jersey Zinc Co. of Pennsylvania, Palmerton, Pennsylvania:

Zinc-rich paint offers its greatest advantages where the intended use involves continuous moisture contact or actual submersion. The high concentration of metallic zinc provides lasting cathodic protection to the steel substrate. In ordinary rural use the standard 80-20 type zinc dust paint should give satisfactory service and is lower in cost and easier to apply.

Any discussions of this article not published above will appear in the December, 1957 issue.

Coal Tar Coatings for Protection Of Underground Structures★

By NORMAN T. SHIDELER

Introduction

THERE ARE records on the use of coal tar coatings for the protection of underground structures against corrosion dating back more than 40 years with many of the original structures still protected and still in service.

The coal tar coatings are the accepted coatings for the protection of steel water pipe by the American Water Works Association. Their use on water pipe started about 1912, although records dating back much further than this exist. For more than 100 years cast-iron pipe has been dipped in pipe dip coal tar as the pipe is produced; many such coatings have stood the test for many years.

The use of the coatings on oil and gas transmission lines goes back to about 1915. Some of those early lines were in use many years before being removed for replacement in other services.

It is rather surprising to have a type or system of products maintain their position over such a long period of time. This position is held mainly because of the nature and characteristics of the coal tar pitches and the products produced from them. The coal tar pitch base coatings have no water absorption other than what may be absorbed as a surface film. Underground, under water, or out of direct sunlight, there is no deterioration of the coatings. This is proven practically by the long service records available on coatings applied both on water lines, oil and gas transmission lines and other structures underground. Even the most carefully-run laboratory test over long periods of immersion show very little water absorption. This low water absorption combined with a natural stability of the coal tar pitches, their inertness, resistance to mild acids and alkalies, give ample proof of their suitability for the protection of metal surfaces.

During the past six or seven years, a number of talks have been given and articles published in magazines concerning the nature of the coal tar coatings, their production and their characteristics. For this reason, it is not necessary to go into detail with regard to the manufacture of the coatings.

Coal tar coatings fall into two separate groups: (1) Hot Applied Coatings (i.e., those that must be heated for application to metal surfaces), and (2) Cold Applied Coatings (i.e., coatings that can be applied by brush, spray or roller.)

NORMAN T. SHIDELER is Manager of the Protective Coatings Division, Pittsburgh Coke and Chemical Company, Pittsburgh, Pennsylvania. He received a BA degree in chemistry from Indiana University in 1926. Since 1930 he has been associated with several companies, all dealing with coal and in general with coal tar coatings. Mr. Shideler spent six years in the research laboratories of Reilly Tar and Chemical Corporation and two years in sales. He was with the Wailes-Dove-Hermiston Corporation (later the Koppers Company) until 1948 at which time he became associated with Pittsburgh Coke and Chemical Company, starting their production of coal tar coatings. For the past 17 years he has been handling development, production and sales of coal tar coatings exclusively.

Abstract

The history of the use of coal tar coatings for the protection of underground structures is discussed briefly. Specifications are given for the following hot applied coatings: narrow range enamel, moderate range enamel, wide range enamel, AWWA enamel C 203-4 and hot pipeline enamel. Temperature ranges at which these coatings can best be used are shown graphically. Recommendations are made regarding the selection of a coating for a given underground condition.

Specifications are given for a cold applied coal tar coating which has been used successfully by the Bureau of Yards and Docks and by the Bureau of Reclamation. The coating has a variety of names in industry and is a thick, almost non-flowing, thixotropic material produced basically from a coal digestion pitch. 5.4.5

The first hot applied coating still on the market, was one to which has been applied the term "Narrow-Range Enamel." It is produced from a homogenous mixture of selected coal tar pitch and a selected mineral filler to give the best possible service underground and have maximum ease of handling in application. This coating was the only hot applied coating on the market until approximately 1932, when a new system of coal tar coatings was developed known as "coal digestion products." These coatings are made from coal tar pitch, coal tar heavy oils and bituminous coal, all carefully selected and processed to produce a base pitch, which is combined with mineral filler to produce the finished coating. With the advent of the coal digestion pitch coatings, it became possible to vary the characteristics of the coatings over extremely wide ranges as

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compared to the original narrow-range coating, frequently called "Filled Pitch Coating."

The narrow-range coating is termed "narrow-range" because of the limited temperature range through which the coating may be used. Straight coal tar pitch (the residue from the partial distillation of coal tar) has excessive cold flow characteristics. In other words, a piece of the pitch, which may be sufficiently hard or high in softening point to shatter easily when struck with a hammer, will flow and flatten out at normal temperatures when left undisturbed.

The prevailing specification for the narrow-range enamels today calls for a softening point range of 190-200 F. This coating, applied to metal surfaces and subjected to temperatures below 30 F, will crack and disbond from the metal because of cold temperature. This same coating on vertical surfaces exposed to temperatures above 110 F will tend to flow and sag from the metal surface. Thus, its safe, useful temperature range is quite narrow, being only approximately 80 degrees F. Increasing the softening point of the base pitch increases the high temperature resistance, but at the same time decreases its resistance to low temperature. The reverse of this is true when the softening point is lowered. Therefore, nothing is gained by raising or lowering the softening point of either the coating or the base pitch.

The developement of the coal digestion pitches made possible great changes in the high and low temperature resistance and other characteristics of the coatings without losing any of the corrosion resistance of the original narrow-range enamel. Coal digestion pitches may be made as hard to the touch as straight coal tar pitches, yet the safe, useful temperature range of such pitches may be double that of the straight pitch. The coal digestion pitches may be made so soft that they will feel like a soft wax, yet their flow characteristic may be such that they would not flow from a vertical surface at temperature as high as 225 F. Thus, the coal digestion makes it possible to produce coatings that meet special requirements which may be very wide in nature. To a certain extent this has been done in the production of the four major coal digestion products available from the stock of the suppliers today. These four coatings are familiar to most engineers. In general terms they are the Moderate-Range Enamel, Wide-Range Enamel, American Water Works Specification Enamel, and Hot Pipeline Enamel. The characteristics of the range of coatings currently available can best be interpreted by looking at the general specification limits of these four enamels and the Narrow-Range Enamel, shown in Table 1.

Table 1 gives the characteristics of these various coatings as indicated by their analysis, based on softening point, penetration, ash, sag test and cold-cracking temperatures. The effect of coal digestion on the characteristics of the coatings is most noticeable in: (1) the penetration (a measure of softness, and in some cases a measure of cold flow); (2) the sag test, and (3) the cold-cracking temperatures of the coatings.

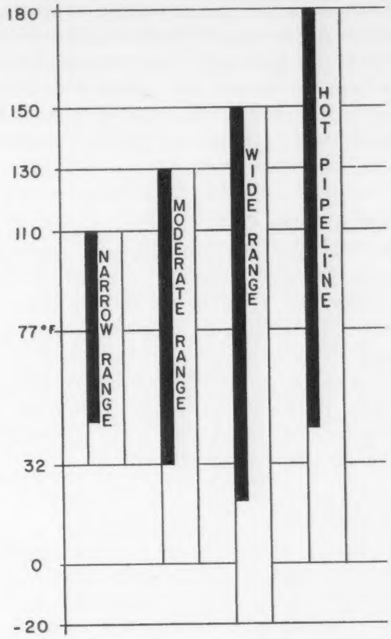

Figure 1—Graphic temperature range chart for use of coal tar coatings. Large blocks represent in-service temperature use. Shaded blocks represent maximum safe temperatures for handling coated pipe.

TABLE 1—Typical Specifications—Coal Tar Hot Applied Coatings

TEST	Narrow Range Enamel	Moderate Range Enamel	Wide Range Enamel	AWWA Enamel C203-4	Hot Pipeline Enamel
Specific Gravity at 25 C.	1.45-1.55	1.40-1.50	1.40-1.50	1.40-1.50	1.40-1.50
Softening Point (Degrees F ASTM D-36).......	190–200	195–205	220 minimum	220 minimum	240 minimum
Penetration ASTM—D-5					
100 g, 5 sec, 77 F.....	0–2	2–6	7–11	10–20	1–3
200 g, 5 sec, 77 F.....	.....	.....	.....	.....	2–6
50 g, 5 sec, 115 F....	2–8	8–20	14–28	15–55	5–15
Ash, Mineral Filler Percent by Weight....	20–25	20–25	20–25	25–35	25–35
Sag Test					
7 hours at 120 F.....	1/16" maximum	.....	.....	.....	.....
7 hours at 140 F.....	.....	1/16" maximum	.....	.....	.....
24 hours at 160 F.....	.....	.....	1/16" maximum	1/16" maximum	.....
24 hours at 180 F.....	.....	.....	.....	.....	1/16" maximum
Cold Cracking Test					
5 hours at 30 F.......	None	.....	.....	.....	.....
5 hours at 0 F.......	.....	None	.....	.....	.....
5 hours at —10 F.....	.....	.....	.....	.....	None
5 hours at —20 F.....	.....	.....	None	None	.....
Spark Test 10,000 volts Low Amperage.......	None	None	None	None	None

Narrow-Range Enamel

The Narrow-Range Enamel on the basis of test has an indicated useful temperature range of 30 F to 120 F. Its hardness, as far as penetration is concerned, is approximately zero at room temperature.

Moderate-Range Enamel

The Moderate-Range Enamel has the same soften-

ing point range as the narrow-range product, yet the useful temperature range is increased to extend from zero to 140 F. At the same time that its temperature range has been increased, the softness of the coating to penetration is increased, and the coating is no longer hard and brittle, as is the narrow-range enamel.

Wide-Range Enamel

Adjacent to the above-mentioned coating is the Wide-Range Enamel. Here is a coating with a temperature range of —20 F to 160 F. This product normally is soft enough so that it can be penetrated by pressing on it with a finger nail, soft enough so that at room temperature the coating is quite flexible, may be bent, twisted, etc., without damage, and yet having a softening point 20 to 40 degrees F above that of the narrow-range enamel.

Water-Works Enamel

The Water-Works Enamel is listed primarily to show the difference in the softness that can be produced in the coatings with much the same useful temperature range still being maintained. In this product, softening point, filler content, sag test, and cold test temperature are the same as for the normal wide-range coating. However, here is a case where the majority of the coating is produced with an average penetration of about 16; in other words, the coating is quite soft, yet its other characterstics have not changed.

Hot Pipeline Enamel

The Hot Pipeline Enamel specification shows still another extreme in the changes that can be made. There, the minimum softening point is 240 F. The sag test temperature of the coating on a vertical surface is 180 F plus, and the cold-cracking temperature is at zero or below. Yet this same coating is almost as hard to the feel as is the narrow-range enamel. The temperature ranges of the coatings can best be shown graphically in Temperature Chart (see Figure 1).

The question that probably occurs after looking at these specifications is what does all this mean with regard to the protection of pipelines or metal structures underground? In gas pipelines particularly the coated pipe may not in service be subjected to temperatures as low as zero or —10 F, but outside the pumping station may be subjected to temperatures as high as 180 F or higher, continuously. Oil and gas pipelines and other structures may be buried in soils where the soils are continuously moist or wet or the soils may be alternately wet and dry, in which case, the coating may be subjected to soil stress which has a tendency to pull the coating from the pipe or thin it out in spots. Soils may be highly acid or highly alkaline. The coated pipe may be subjected to stray current corrosion, which requires a coating that does not absorb water and a coating that retains a fairly high dielectric strength. All of these points lead to one specific statement that no one coal tar coating can fit the requirements of all conditions.. In addition, existing conditions during application must be considered.

Some years back, coatings were sold with each manufacturer pointing out the ease of application and handling of the coatings, with very little reference being made to the performance of the coating underground. In recent years, it has been found that it is more important to select the coating for conditions in service underground than conditions during application. All of this leads to one definite conclusion: in the use of a protective coating, whether it be coal tar or otherwise, the coating should be selected to fit the conditions and performance required of the coating on the underground structure.

From the data given in Figure 1, some specific recommendations with regard to the proper coating for the underground conditions can be made (see Table 2).

One point in caution should be made in using the above mentioned summary of coating uses. All statements are made exclusive of application conditions. In application the most serious stumbling block is low temperature at the time of application. It is known that the hot applied coatings have been applied to metals at atmospheric temperatures as low as 0 F. Common sense says that this should not be done at temperatures below 35 F for best results. At lower temperatures, moisture must be driven off the metal by preheating the metal; primers dry slowly and are apt to be wet when the coating is applied. In addition many other dangers exist.

A second consideration involves the handling of the coated structure at low temperature. The cold-cracking temperature indicates the safe low temperature at which the coated structure can stand undisturbed without the cold causing the coating to crack and disbond. If the structure is to be handled or flexed at low temperatures, such temperatures are much higher as shown in Table 3.

The gist of this discussion thus far has been to

TABLE 2—Recommended Coatings for Service Underground

Underground Conditions in Service	Recommended Coating
1. Smooth dirt backfill; little or no soil stress; operating temperature not above 110 F, nor lower than 30 F.	Narrow-Range Enamel
2. Average soil, backfill and soil stress; operating temperature not above 130 F, nor lower than 0 F.	Moderate-Range Enamel
3. Smooth backfill, no stones, average soil stress; operating temperature not above 150 F, maximum low —20 F	Wide-Range Enamel
4. Water Works structures, smooth backfill, no soil stress; operating temperature not above 140 F; for coating and lining	AWWA Enamel
5. Water Works structures, average soil and backfill; operating temperature not above 150 F	Wide-Range Enamel
6. Rough, stony backfill; high soil stress; operating temperature above 140 F	Hot Pipeline Enamel

TABLE 3—Safe Handling Temperatures for Coated Structures

Type of Coating	Safe Low Temperature Exposure Undisturbed Structure	Safe Low Temperature for Careful Handling of Structure
Narrow-Range	30 F	50 F
Moderate-Range	0 F	30 F
Wide-Range	—20 F	20 F
AWWA	—20 F	15 F
Hot Pipeline	0 F	40 F

point out that when an underground structure is to be protected with a coating, the purchaser should consider all the conditions that will exist on the underground structure when that structure is placed in service and should, to a certain extent, consider the application difficulties that may exist at the time of construction. From the standpoint of application, there is really only one point to consider and that is, "will the coating selected withstand the temperatures existing at the time of application?"

All grades of coal tar coatings on the market today are fairly easily applied and only the atmospheric temperature that may exist at the time of application is of real concern. If a pipeline is to be operated at fairly high temperatures, (i.e., above 140 F), it is not reasonable to use a narrow-range or moderate-range coating. The wide-range material will stay on the pipe; however, if operated at temperatures of 140 F or more, the coating will be so soft that any rough backfill will puncture the coating and create voids or require additional cathodic protection. If the underground structure is to be subjected to extremely high soil stresses, as occurs frequently in the southern part of the United States, the hot pipeline coating is ideal for such operations, as well as being ideal for high-temperature lines.

This brings up another point which is critical in the selection of coatings and their use. When a coating is specified there should be some assurance that the coating supplied meets the specification desired. How important this is can be best demonstrated by pointing out one condition that resulted from off-specification material a few years back. Two coatings, basically supposed to meet the same specification, were applied to a pipeline leading from two different pumping stations on the same line. One and one-half years after the line was placed in service, cathodic protection current requirements at one station increased to the point that the current required was equivalent to a bare pipe. It was known that the pipeline was operating at approximately 130 to 140 F, and a moderate-range enamel had been specified. Examination of the pumping station where failure occurred and an examination of the other pumping station where no failure existed showed that the failure was due to the enamel sliding from the pipe, leaving a major portion of the pipe unprotected. Subsequent analysis of this coating indicated that its original softening point could not have been higher than 170 F, whereas the specification called for 190 to 200 F. Thus, it is important in the purchase of coatings that the coating supplied falls within the specification.

It has been indicated that there are five specific specification coal tar coatings available at all times, but what has not been indicated is that in many cases the manufacturer can formulate the coal digestion type products to meet a very wide range of specifications. This can be done with no effect on production as long as the amount of coating required fits into the batch operation for the production of the coatings. For instance, if the normal batch in a plant is 60 tons of enamel, on an order for a material meeting a special specification, any quantities in multiples of 60 tons would require no radical changes over normal grades for production. There are occasions where underground structures may require special coatings, and the coating manufacturers can produce them to fit the needs of the structure.

In all of the foregoing, only the hot applied coatings have been considered. Cold applied coatings have been frowned on for underground structure protection. However, in spite of much hesitancy on the part of industry, one of the cold applied coal tar coatings, in particular, has given exceptional service when applied to pipelines, structural steel and other such structures for underground protection. This coating has a variety of names in industry, but is a thick, almost non-flowing, thixotropic, cold applied coating, produced basically from a coal digestion pitch, similar to that used in the manufacture of the wide-range enamel. In fact, the coating after drying has almost identically the same specification and characteristics as does the Wide-Range Enamel. This coating has been supplied for many years to the Government under Bureau of Yards and Docks Specification 34YB. It has been used by the Bureau of Reclamation under Specification CA-50. Industrially, the coating has been used underground for more than 20 years successfully on tanks, structural steel and pipelines. In the past few years, considerable amounts of this coating have been used for the reconditioning of short sections of lines, coating of small distribution lines, patching and repair work. Results of such applications have been excellent. It is true that the coating thickness is only approximately 1/32 inch; however, with reasonable care in application and the application of controlled cathodic protection, this coating will give lasting protection. The specification of this material, as supplied under 34YB, is given in Table 4.

In the coating of straight pipe with the cold applied coating, the best application is a combination of this coating and the use of a tar-saturated glass mesh. Although the glass mesh has a thickness of only about 5 mils, the cold applied coating applied to the pipe followed immediately by a double wrap of the glass mesh, pulled tightly, and this followed immediately by a final brush smooth-out coat, will result in a uniform coating thickness of 25 to 30 mils. This makes an ideal coating which can be highly recommended for such applications.

Cathodic protection has been mentioned in conjunction with the coatings. The use of cathodic protection with the coatings not only fortifies the coated structure, but is sound economics. Any attempt to apply a coating that is 100 percent perfect without faults or voids is pratically impossible, and any at-

TABLE 4—Department of the Navy Bureau of Yards and Docks Specification 34YB*

	Minimum	Maximum
Distillate by Weight:		
% to 235 C	20	30
to 150 C	..	None
Softening Point of Residue (Degrees F)	205	240
Penetration of Residue at 77 F, 100 g, 5 sec	5	..
Ash, by Weight:		
Total Coating %	15	25

* Section 1-05 Coal Tar Base Coating

tempts to approach perfection increase application costs drastically. Also, in service, damage may occur to the coating after installation which will expose small areas of bare metal which can be protected easily and cheaply with cathodic protection. Thus, coatings applied with reasonable care and the application of controlled cathodic protection will ensure lasting economical protection. Although there is not too much data available, the cathodic protection applied either by anodes or rectifiers should be controlled. The individual concerned should apply just enough voltage and amperage to protect.

This coatings discussion has dealt with the present two types of coal tar coatings. New coal tar coatings are being developed and it is hoped that improved coatings will be placed in the hands of the engineers as developments progress. These may be combinations such as combination of a coal tar phenol-formaldehyde resin or the coal tar epoxy coatings and others of this nature.

Any discussions of this article not published above will appear in the December, 1957 issue.

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Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

Some Case Histories of Stress Corrosion Cracking Of Austenitic Stainless Steels Associated With Chlorides★

By H. R. COPSON and C. F. CHENG

Introduction

EVER SINCE the appearance of a paper by Hodge and Miller[1] it has been recognized that the austenitic stainless steels are susceptible to transgranular stress corrosion cracking in chloride solutions under certain conditions. This has been amply confirmed by numerous laboratory tests on stressed specimens in boiling concentrated chloride solutions.[2,3,4,5,6,7,8,9] While some service failures in such solutions have been reported,[7,10,11] hot concentrated chlorides are not always an obvious factor in the environment. An insidious type of failure occurs where the chloride concentration initially is quite dilute, as for example in plain water or steam. In spite of the numerous papers which have been published, references in the literature to service failures of this type remain rather infrequent and brief.[7,11,12,13,14,15,16] Some attempts have been made to reproduce this type of cracking in the laboratory.[17,18,19,20] Nevertheless it is difficult from the literature to build up a realistic picture of the stress corrosion cracking problems which may arise from the ever increasing use of these alloys.

Over the years this laboratory has had the opportunity to examine many cracking failures of austenitic stainless steels. Many of these failures have been attributed to stress corrosion cracking associated with chlorides. Some 22 well authenticated cases are described in this paper. Many other cases were recognized as similar failures on the basis of experience or appearance, but these 22 required laboratory examination in order that a diagnosis could be reached at the time they occurred.

It is hoped that this presentation of case histories will make it easier to identify and to avoid similar difficulties. It should be emphasized, however, that predictions are a risky business and that there are many situations where stress corrosion cracking does not occur in practice. Stainless steels are widely and successfully used in many applications involving chlorides.

Since all the failures described involve conditions where chlorides can concentrate and build up to high values locally at least, it appears satisfactory in the laboratory to use boiling concentrated chloride solutions to study some aspects of this problem.[21] Following the case histories, the results of some laboratory tests in such solutions are presented. These indicate that resistance to cracking increases with nickel content, and that large additions of nickel bring about a major improvement. This latter subject is currently being investigated more exhaustively. Inconel (77 percent nickel, 15 percent chromium, 7 percent iron), which is at the high nickel end of this series of alloys, is regarded as immune to this type of stress corrosion cracking.

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Abstract

Some 22 case histories of stress corrosion cracking in Types 302, 304, 316, 321, and 347 stainless steels are presented. These occurred in water, steam, brines, and miscellaneous solutions. In each case, either the chloride content was high initially, or conditions were such that chlorides could concentrate. Usually the temperature was quite hot. Often the environment was acid and in most cases it seemed likely that air was present. Microexamination always revealed transcrystalline cracks which usually had a characteristic branching growth. In each case it was concluded that internal tensile stresses in combination with concentrated chlorides caused the cracking.

Some means of avoiding cracking are pointed out. Following the case histories the results of some laboratory tests are presented which show that resistance to cracking increases with nickel content, and that large additions of nickel bring about a major improvement. Inconel, which is at the high nickel end of this series of alloys is considered immune to this type of stress corrosion cracking. **3.5.8**

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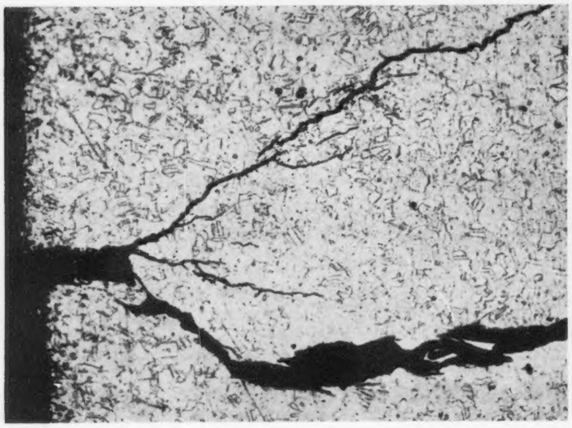

Figure 1—Cross section of tubing of Case 1 showing cracking at outside surface. Electrolytic oxalic acid etch, 100X.

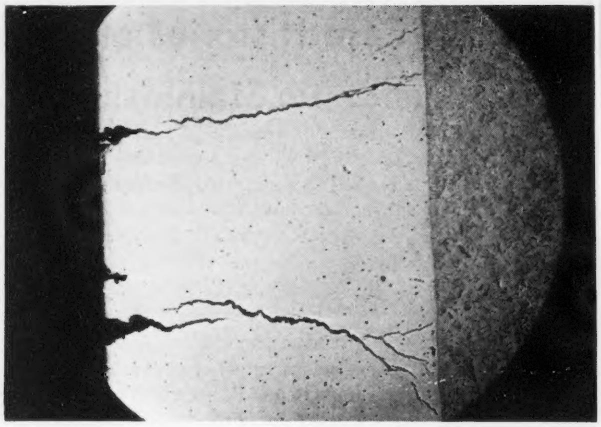

Figure 2—Cross section of flash shield of Case 14 showing cracks. Electrolytic oxalic acid etch, 100X.

TABLE 1—Stress Corrosion Cracking Failures in Hot Concentrated Chlorides

	SERVICE CONDITIONS					STAINLESS STEEL			
Case	Environment	Temp. Maximum Degrees F	Chlorides Minimum PPM	pH Min.	Aeration	Type No.	Hardness Maximum VHN_{pd}	Thickness Inch	Time to Failure Months
1	Evaporated Water	380	18	7.3	Present	304	162	0.06	6
2	Evaporated Water	249	Low	6.8	Present	316	—	0.06	Few
3	Evaporated Water	570	Low	—	Present	321	142	0.06	—
4	Evaporated Water	240	200	6	—	304	172	0.07	12
5	Evaporated Water	250	4	7.7	Present	304	135	0.05	—
6	Evaporated Water	220	Low	Acid	10 PPM	304, 316	—	0.03, 0.13	8
7	Steam	518	High	—	Present	316	—	0.08, 0.23	2
8	Steam	250	Low	—	Present	302	—	0.06	3
9	Steam	475	10	3.5	—	316	190	0.20	4
10	Steam	500	Low	—	—	304	—	0.06	9
11	Brine	Boiling	High	—	Present	302, 304, 316	Annealed	0.03	1
12	Brine	Boiling	High	—	—	347	190	0.07	<< 1
13	Brine	Hot	High	—	—	18-8	—	0.15	—
14	Glutamic Acid	176	High	5.6	—	302	—	0.19	6
15	Levulinic Acid	Hot	Present	Acid	—	316	Annealed	0.03	1
16	Cereal	Hot	High	—	Present	304	165	0.25	21–36
17	Bean Sauce	Hot	26,000	Acid	Present	304	—	0.10	20
18	Tar Acids	250	Present	Acid	—	304, 316	Annealed	0.03	2
19	Tar Acids	650	Present	Acid	—	316	—	—	1
20	Filter Aid and Oil	325	Present	—	—	304	—	0.10	<< 1
21	Pulping Process	—	1400	Acid	—	316	279	0.13	—
22	Chlorinated Solvents	—	Present	Acid	Present	316	160	0.03	5

Case Histories

Some of the conditions surrounding the cracking failures are summarized in Table 1. The first six cases involved exposure to water which evaporated and concentrated. The next four involved exposure to steam, the next three to brines, and the remainder were exposed under a variety of conditions. In each case, either the chloride content was high initially, or conditions were such that the chlorides could concentrate. Usually the temperature was quite hot. Often the environment was acid and in most cases it seemed likely that some air was present.

The cracking ocurred in Types 302, 304, 316, 321, and 347 stainless steel. From a practical point of view these alloys can be considered equally susceptible. Hardness and thickness seemed relatively unimportant. Failures took anywhere from a few days to a few years or even longer to occur. In each case it was concluded that internal tensile stress in combination with exposure to concentrated chlorides caused the cracking.

In each case microexamination showed that the cracking was transcrystalline. Occasionally the cracks were fairly straight and few in number. Much more often they were profuse and had the branching growth shown in Figures 1, 2 and 3. Sometimes this branching growth was evident on the surface as shown in Figures 4, 5 and 6. The particulars of each case are given in detail below.

Case 1

A gas cooler had vertical Type 304 stainless steel tubes, ⅝ inch in diameter. Lake water was outside the tubes, but it did not completely fill the unit, there being an air pocket above the overflow. Hot gas entered the tubes at the top at 380 F. After six months cracks developed in the vicinity of the water level.

The water level fluctuated due to surging. As a result the water evaporated, concentrated, and produced a corrosive condition. In the area of the cracking there was a rusty deposit on the outside of the tubes, and numerous shallow pits filled with black corrosion product. Qualitative tests on the rusty deposits showed that considerable chloride was present. Initially the water contained 18 ppm of chlorides.

Cracks extended from most of the pits. Microexamination confirmed that the cracks started from

Figure 3—Cross section of stainless steel of Case 21 showing cracking. Etched with glyceregia, 100X.

the water side. Figure 1 shows their typical appearance. The cracks tended to spring open indicating that internal stresses were present. Slitting an uncorroded piece of the tubing showed a circumferential tensile stress of 24,000 psi.

This cracking might have been prevented by eliminating the air pocket, by reversing the flow of the gas so that the hot gas entered the bottom of the tubes, or by passing cooling water through the tubes and having the hot gas outside. The failure was similar to one described by J. A. Collins.[16]

Case 2

This failure was similar to Case 1. It involved ¾ inch diameter Type 316 tubes in a vertical condenser. Both the cooling water and an organic distillate entered at the top. The entering temperature of the distillate was 240 F. The water was on the shell side, and there was an air space above the water level. After a few months the tubes cracked just above the liquid level. The cracks started from the shell side, and there was rusting and pitting in the area of the cracks. The circumferential stress in the tubes measured 18,000 psi.

Case 3

This case was quite similar to the preceding ones. The cooling water was inside the tubes, but it overflowed near the upper capped ends of the tubes into smaller drainage tubes located inside. Thus again there was an air pocket near the top of the tubes. The outside of the tubes was exposed to gases at 570 F. As might now be expected stress corrosion cracking developed from the inside of the tubes at the level of the overflow. The tubes in this case were Type 321 stainless steel. The circumferential internal tensile stress measured 14,000 psi. The internal stresses probably were higher than this near the capped ends.

Case 4

Bayonet U-type heaters were fabricated from Type 304 stainless steel tubing ¾ inch in diameter. The tubes were not heated after bending so that high internal stresses would be expected to be present.

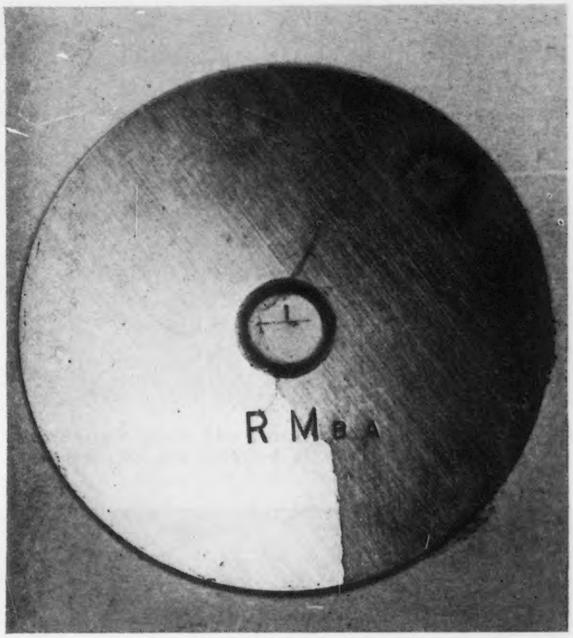

Figure 4—Part of screw conveyor of Case 13 showing cracks. ½X.

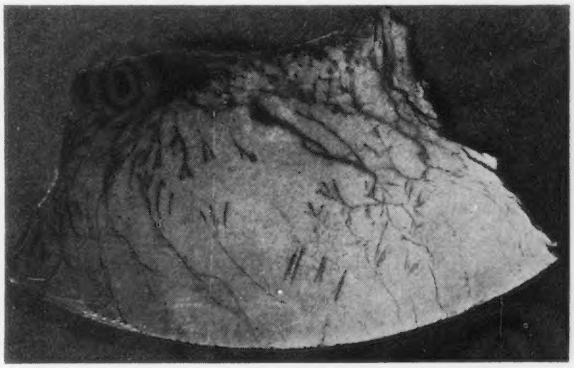

Figure 5—One of the cracked disc specimens of Case 15. 1X.

Figure 6—Cracking in bottom of kettle of Case 17. 1X.

The U-tubes were used in a batch process which involved exposure on the inside to steam and water. Steam at 240 F was introduced into the tubes to start the reaction. The reaction was exothermic and well water containing 200 ppm of chlorides was then injected for cooling. This procedure was repeated many times. By 12 months numerous typical stress corrosion cracks developed on the inside surface. Cyclic

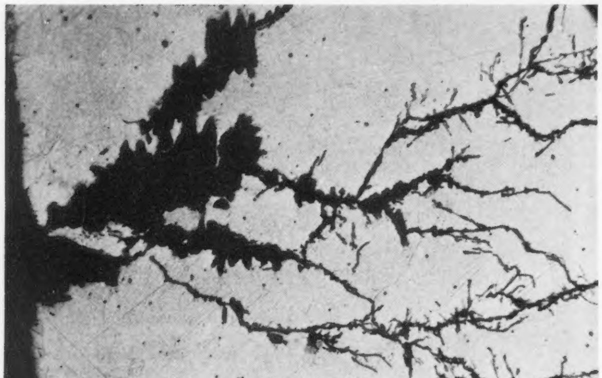

Figure 7—Cross section through stainless clad steel of Case 7 showing cracks stopping at the steel. Nital etch, 25X.

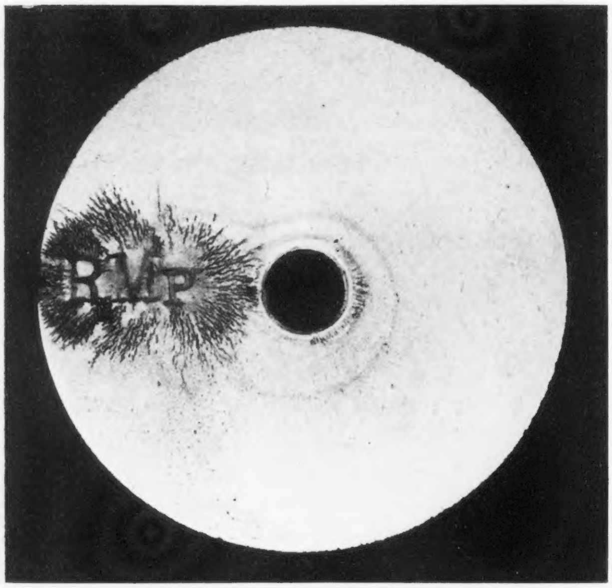

Figure 8—Section through expansion joint of Case 10 showing cracking at inside surface. Electrolytic oxalic acid etch, 250X.

exposure to steam and hot water has caused similar cracking in laboratory tests.[18]

Case 5

A boiler feedwater deaerating heater had Type 304 stainless steel trays arranged one above the other and heated by steam. The trays had three sides bent upwards and one side bent downwards, so that water drained from one tray to the next. Fabrication by bending and welding introduced high stresses. Some trays were buckled. Cracking started at the upper sheared edges of the trays where water at 250 F happened to spill over. The cracking spread widely following the drainage path of this intermittent spillage. There was no cracking where the trays were continuously wet. The cracks were filled with black oxide, which sometimes was massive. The oxide exerted pressure as shown by the splitting and lifting of some areas.

The water had an average chloride content of 4 to 5 ppm and a maximum chloride content of 10 to 12 ppm. Qualitative tests detected chlorides at the upper sheared edges and along the cracks but not elsewhere on the trays. It seemed clear that the cracking occurred where water could evaporate and concentrate. A rather similar stress corrosion cracking failure of stainless steel trays in a feedwater deaerating heater was described by R. A. Lincoln.[22]

Case 6

A corrosion test spool was exposed in the path of sprayed influent water in a boiler feedwater deaerating heater. Upon removal after eight months, some of the Types 304 and 316 stainless steel specimens on the spool had numerous stress corrosion cracks at the punched center hole at areas partially shielded by a Bakelite spacer. Some cracks ran parallel to the surface and lifted up circular flakes of metal. A dark oxide phase was present in the cracks and this seemed to have caused the metal to swell.

The maximum temperature of the water was 220 F. It contained 10 ppm of oxygen, 30 ppm of sulfuric acid, and 70 ppm of carbon dioxide. Analyses were not made for chlorides, but traces were thought to be present. The chlorides evidently concentrated in the crevice between the specimen and the spacer. Other instances have been cited in the literature where chlorides concentrated in crevices and caused cracking.[16, 18]

Case 7

In a semi-chemical pulping plant, steam at 437 to 518 F was injected into a chamber containing wood chips. Within two months both the Type 316 steam inlet nozzles and the Type 316 lining of the chamber had cracked in the vapor phase region above the wood. Many cracks in the lining stopped when they reached the steel backing. This is illustrated in Figure 7.

Before entering the chamber the wood had been floated through salt water. Impingement of live steam on the raw wood caused spattering with the result that chlorides concentrated in places normally exposed only to vapor. Many cracks were located near welds and appeared to originate at deep pits. The cracks tended to spring open showing that internal stresses were present.

Case 8

Some sterilizing baskets were made of Type 302 stainless steel. These had a diamond lattice type of pattern which was produced by slitting a sheet of metal and expanding. This method of construction undoubtedly introduced high internal stresses. After three months intermittent exposure to steam at 250 F, profuse cracking developed in the sides and bottoms of the baskets. The metal was rusted and most of the cracks started at a nick or pit which served to concentrate the internal stresses. Qualitative tests showed that a surprising amount of chlorides was present, presumably through spillage. Eliminating the spillage, keeping the baskets clean, and stress relief annealing might have prevented these failures.

Case 9

A 1.9 inch diameter Type 316 pipe was used to transfer excess steam at 475 F from a reaction vessel. There were some entrained solids and liquor in the flow stream, primarily sulfates. Samples of steam condensate ranged in pH from 3.5 to 4.5, and had a chloride content of 10 to 20 ppm. After about four months in service, cracks appeared at a bend in the pipe. The pipe had been bent cold and no annealing treatment was applied after bending.

Examination of the pipe showed that the inside had a black scale overlaid by a rust colored deposit. Qualitative tests showed that chlorides were present. The cracks were confined to the bend and started from the steam side. There were no cracks in straight portions of the pipe. The hardness of the straight portions were 133 $VHN_{30\text{-}pd}$, and of the bent portion 190 $VHN_{30\text{-}pd}$.

A stress relief anneal to reduce the internal stresses at the bend would prolong the life of the tube, but it is difficult to get the stresses low enough to completely prevent cracking in time.[23,24] It is important to keep the steam clean and dry if possible.

Case 10

A Type 304 corrugated expansion joint in a steam line at 500 F cracked in nine months. Microexamination showed typical transcrystalline cracks penetrating from the steam side, as shown in Figure 8. The cracking was confined to areas where stains indicated that condensate had collected in the corrugations. It was concluded that chlorides concentrated at these areas and that high internal stresses in the corrugated structure caused the cracking. Somewhat similar failures have been described by F. W. Davis.[14,15]

Case 11

In 1939 an instance of stress corrosion cracking was encountered on a corrosion test spool exposed for one month half immersed at the liquid level in a boiling 40 to 50 percent calcium-magnesium chloride brine. All the stainless steel specimens on the spool cracked at the stamped identification letters and in some cases at the machined edges. A typical specimen is shown in Figure 9.

It is now well known that this type of environment is very effective in producing stress corrosion cracking of austenitic stainless steels. In 1939, however, this phenomenon was quite new. The effect of heat treatment was tried.[23] Specimens water quenched from 1950 F cracked even more profusely than as-received specimens, but the cracks no longer passed through the stencil marks. Heating relieved the internal stresses at these points, but the quenching stresses were high enough to cause cracking. Heating at 1350 F for one hour followed by furnace cooling lowered the stresses sufficiently to prevent cracking in this case. In other cases it has been found necessary to use higher stress relieving temperatures to prevent cracking.[4,8,24]

Case 12

In an emergency some Type 347 tubes, which happened to be available, were installed in a magnesium chloride evaporator. In the hope of preventing cracking, the tubes were stress relief annealed at 1350 F and furnace cooled. They were not rolled into the tube sheets but were held in place by packing rings. In spite of this stress corrosion cracks developed all over the tubes after only a few days in service.

Subsequently the cracking of these stress relieved tubes was reproduced in the laboratory. In these tests it was found that heating at 1600 F followed by slow cooling did suffice to prevent the cracking in laboratory tests lasting 36 days.[24]

Case 13

A stainless steel screw conveyor was used for handling hot wet salt. Typical stress corrosion cracks soon developed on the blades. Figure 4 shows their appearance. A similar failure was described by H. J. Rocha.[25]

Case 14

A Type 302 flash shield was installed in an evaporator handling glutamic acid. Large quantities of sodium chloride were known to be present. The shield was wetted by spray from the inlet nozzle but never submerged. The temperature was 176 F and the pH 5.6 to 6.0.

After six months the shield was profusely cracked. Its appearance is shown in Figure 10. It was coated with a black scale but seemed uncorroded. Pitting was apparently absent. Microexamination revealed typical branching transcrystalline cracks as illustrated in Figure 2.

Case 15

A corrosion test spool was exposed in hot levulinic acid containing some formic acid and some hydrochloric acid. When removed after one month the Type 316 stainless steel specimens on the spool were profusely cracked around the stamped identifying code letters. The cracking is shown in Figure 5.

Case 16

Type 304 stainless steel was used for lifting flights in a cereal cooker. Welded construction was used which undoubtedly introduced internal stresses. The flights were exposed to corn, wheat, bran, salt and flavoring extracts. The cooking was done by steam. After two to three years there were profuse stress corrosion cracks all over the flights. The cereal had burned on. The surfaces were coated with black scale and were corroded and pitted. Qualitative tests confirmed the presence of large amounts of chlorides in the scale.

Case 17

A Type 304 kettle handling baked bean sauce cracked all over the hemispherical bottom by 20 months. Figure 6 shows the radiating pattern of the cracking. The kettle was of welded construction and was heated by a steam jacket. Sometimes this type of construction has caused cracking from the steam side[7] but in this case the cracks appeared to start from pits in the inside as shown in the figure. The sauce contained 22 pounds of salt and 1 pound of

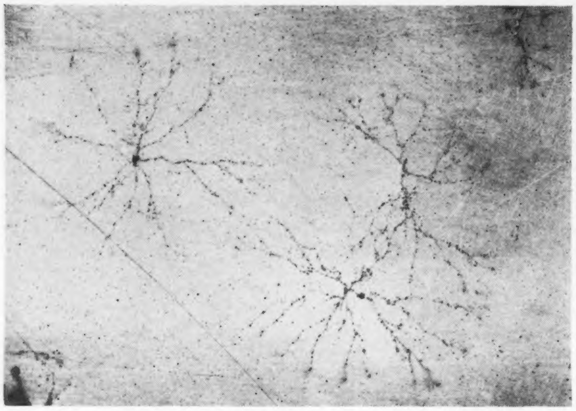

Figure 9—One of the cracked disc specimens of Case 11.

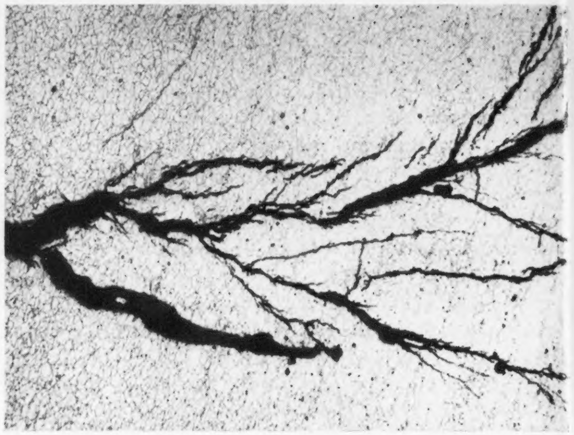

Figure 10—Part of flash shield of Case 14 showing cracks. 1X.

citric acid per 100 gallons, in addition to tomatoes, sugar, starch, and spices.

Case 18

A corrosion test spool was exposed in a tar distillate line at 250 F for two months. Tar acids, tar oils, naphthalene oils, and some chlorides were present. After removing the tar coating on the specimens, numerous cracks were evident in the Type 304 and Type 316 specimens. Rust was present in the vicinity of the cracks.

Case 19

A Type 316 level control in tar distillation service cracked in the flattened fulcrum portion. The temperature was 650 F. Tar, tar acids, and some chlorides were present.

Case 20

A Type 304 wire cloth was used as a pressure filter for neutral oils at 300 to 325 F. After only four runs the cloth started to crumble. Examination showed no appreciable weight loss or general corrosion, but there was profuse transverse cracking on all the wires. Most of the cracks were located on the same side of the cloth as the filter aid. Qualitative tests showed that chlorides were present. The cracks tended to spring open showing that internal stresses were present. This failure might be similar to those described by Dana and DeLong.[19]

Case 21

Type 316 stainless steel was used for making a serrated wire holder for a washer in a wood pulping process. Cracks soon started at the nicks and crevices in the ground surface at the sides of the teeth. In time the teeth broke off. Figure 3 shows the typical branching transcrystalline cracks. The solutions in the washer contained magnesium bisulfite, sulfurous acid, other residual acids, and as much as 1400 ppm of chlorides.

Case 22

A recovery unit for chlorinated solvents utilized activated carbon and Type 316 air distributor screens. The screens were made by punching $\frac{3}{32}$ inch diameter holes in $\frac{1}{32}$ inch thick sheet. This would introduce internal stresses. After five months stress corrosion cracks were very numerous throughout the screen. The attack was similar to that which has been reported in other moist organic chloride compounds.[1,12]

Effect of Nickel Content

Some means of avoiding stress corrosion cracking of austenitic stainless steels have been suggested in the case histories. Much can be accomplished by proper design, not only to keep stresses low, but also to avoid places where chlorides can concentrate. Attention should be paid to the environment to keep chlorides at low levels. The oxygen content and temperature will be important in some cases. Cathodic protection either by contact with a less noble metal or by an applied current is known to be helpful.[8,11,18]

Another means of avoiding stress corrosion cracking is to use resistant alloys. It has been shown that Types 302, 304, 316, 321, and 347 stainless steel are all susceptible to this type of stress corrosion cracking. It has been found, however, that resistance to cracking does increase with nickel content. Rocha[26] reported that alloys containing 10 to 12 percent nickel resisted cracking when exposed to a solution containing 60 percent calcium chloride and 0.1 percent mercuric chloride when loaded in the annealed condition at 28,000 psi and tested for 900 hours. Alloys with this amount of nickel have failed in service and Rocha[26] showed that cold work made them susceptible. This work has been reviewed by Thielsch.[27] Edeleanu[28] reported that alloys containing 16 to 20 percent nickel remained uncracked in boiling 42 percent magnesium chloride when loaded at 90,000 psi and tested for about 500 hours. Other workers have also reported an improvement with increasing nickel content.[5,18] On the other hand Scheil[4] reported cracking in some alloys containing more than 20 percent nickel. Accordingly the question remains as to how much nickel is required for a major improvement.

It should be noted that low nickel contents may also be beneficial, but that the alloys are then no

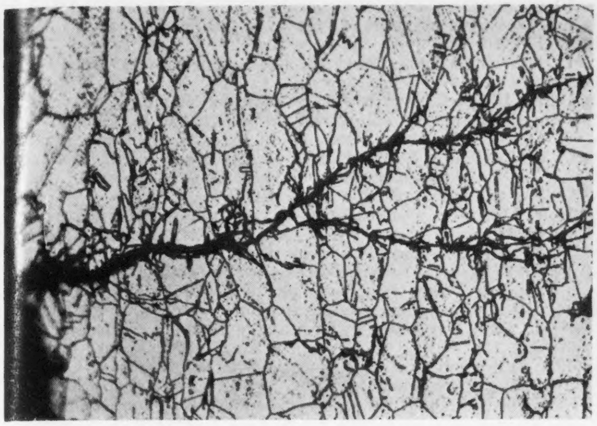

Figure 11—Stress corrosion cracks in test specimen of Material 4 of Table 2. Electrolytic oxalic etch, 250X.

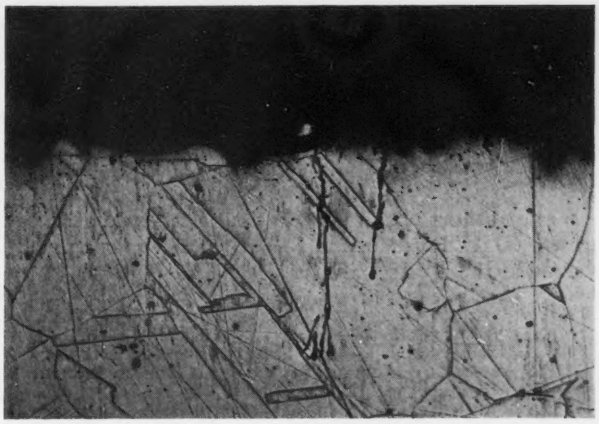

Figure 12—Stress corrosion cracks in test specimen of Material 12 of Table 2. Electrolytic oxalic etch, 100X.

longer austenitic. As the nickel content decreases from the 18-8 composition to the point where a duplex structure of austenite and ferrite is present, the tendency towards stress corrosion cracking is decreased. The high chromium ferritic stainless steel with zero nickel seem resistant to this type of stress corrosion cracking.

Some laboratory data bearing on the behavior of alloys with high nickel content are given in Table 2. Materials of the compositions listed were made into U-bends. To do this annealed material was machined into specimens, 6 x 0.5 x 0.1 inch in size and the surfaces ground; the specimens were then bent into the form of a U and the legs held together with Monel bolts and nuts. To avoid galvanic effects the Monel parts were coated with lacquer and were kept out of the test solution, only the bent portion of the specimens being immersed.

The test solution selected contained 25 percent by weight magnesium chloride and 25 percent by weight calcium chloride and was used at the boiling point. This solution was known to cause rapid cracking of the 18-8 grades of stainless (Case 11 and Case 12).

After two days material 11, which contained 19 percent nickel, had cracked. After 28 days material 6 also showed cracks, but all the other high nickel alloys in Table 2 were still in good condition.

Edeleanu[8] had reported that adding ferric chloride to magnesium chloride solutions made them more aggressive. Following this lead 5 percent ferric chloride was added to the brine and the test continued for a total time of 36 days. Cracks were now visible in several of the alloys and microexamination revealed cracks in still more. Only Incoloy, Inconel, and Monel, materials 5, 9, and 10 respectively, remained free of cracking.

The cracks followed the typical branching transcrystalline pattern. Figure 11 shows the cracks in material 4 and Figure 12 the cracks in material 12.

Composition had considerable effect on the susceptibility to cracking. The 18-8 stainless steels usually fail in this test solution in less than one day. Increasing the nickel content to 19 percent as in material 11 delayed the cracking to two days. Increasing the nickel content still further to 34 percent as in Incoloy, material 5, prevented the cracking in these tests. However, adding molybdenum, chromium, or titanium to the Incoloy composition caused cracking again. Comparing materials 1, 2, and 3 shows that copper was helpful. In the complex alloys containing both molybdenum and copper, high nickel content was beneficial as is shown by comparing the results on materials 4 and 12. These data suggest that elements which tend to stabilize austenite, such as nickel and copper, are helpful, and that elements which tend to stabilize ferrite such as molybdenum, chromium, and titanium are harmful.

TABLE 2—Results of Stress Corrosion Cracking Tests on High Nickel Alloys

Material Number	Composition, Percent				First Observed Cracking Days	Degree of Cracking at 36 Days
	Cr	Ni	Mo	Cu		
11	17.44	19.02	2.00	1.82	2	....
4	20.19	28.78	2.48	2.61	36	Visible
5	20.31	34.24	0.05	0.10	OK	None
7*	21.15	33.63	0.05	0.14	36	Micro Needed
8	21.45	33.29	1.35	0.16	36	Cracked in Two
6	27.66	34.05	0.05	0.09	28	....
1	20.25	38.02	2.24	0.23	36	Visible
2	20.49	37.23	1.98	1.09	36	Visible
3	20.31	37.75	1.99	3.48	36	Micro Needed
12	19.64	40.96	4.03	1.91	36	Micro Needed
9	14.62	78.42	....	....	OK	None
10	....	67.03	....	30.18	OK	None

Test Solution, first 28 days: Boiling 25 percent Mg Cl_2 plus 25 percent $CaCl_2$

Test Solution, 28 to 36 days: Same plus 5 percent $FeCl_3$.

* 0.88 percent titanium.

In some separate tests it was found that Incoloy is not completely immune to this type of stress corrosion cracking. By cold working the material to a hardness of 333 $VHN_{10\text{-}pd}$ it was found possible to cause cracking in the boiling calcium-magnesium chloride brine. The hardness of the Incoloy in Table 2 ranged from 162 to 172 $VHN_{10\text{-}pd}$.

As far as is known Inconel has never suffered this type of stress corrosion cracking. In a number of applications where stainless steels have failed by stress corrosion cracking, Inconel has been substituted and has performed satisfactorily.[29]

It is quite possible that alloys of intermediate nickel content will perform satisfactorily in many applications. Field tests will be necessary to establish this. It seems safe to say that the more drastic the conditions of service the higher will be the nickel content required to prevent failure.

Acknowledgment

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References

1. J. C. Hodge and J. L. Miller. Stress Corrosion Cracking of the Austenitic Chromium-Nickel Steels and Its Industrial Implications. *Trans. Am. Soc. Metals,* **28,** 25 (1940).
2. M. A. Scheil, O. Zmeskal, J. Waber, and F. Stockhausen. First Report on Stress Corrosion Cracking of Stainless Steel in Chloride Solutions. *Welding J.,* **22,** 493s (1943).
3. M. A. Scheil and R. A. Huesby. Studies on Stress Corrosion Cracking of Austenitic Stainless Steels, Types 347 and 316. *Welding J.,* **23,** 361s (1944).
4. M. A. Scheil. Some Observations on Stress-Corrosion Cracking in Austenitic-Stainless Alloys. Symposium on Stress Corrosion Cracking of Metals, published by ASTM and AIMME, Philadelphia and New York, 1945.
5. R. Franks, W. O. Binder, and C. M. Brown. The Susceptibility of Austenitic-Stainless Steels to Stress-Corrosion Cracking. Symposium on Stress Corrosion Cracking of Metals, published by ASTM and AIMME, Philadelphia and New York, 1945.
6. M. H. Springer, E. V. Succup, D. S. McKinney, and M. A. Scheil. An Attempt to Select a Suitable Specimen for the Study of Corrosion Cracking in 18-8 Steel. *Welding J.,* **26,** 530s (1947).
7. H. Nathorst. Stress Corrosion Cracking of Stainless Steels. Welding Research Council Bulletin Series, No. 6, Oct. 1950.
8. C. Edeleanu. Transgranular Stress Corrosion in Chromium-Nickel Stainless Steel. *J. Iron and Steel Inst.,* **173,** 140 (1953).
9. T. P. Hoar and J. G. Hines. The Stress Corrosion Cracking of Austenitic Stainless Steels, Part I—Mechanism of Process in Hot Magnesium-Chloride Solutions. *J. Iron and Steel Inst.,* **182,** 125 (1956).
10. G. A. Dummett. Discussion in Symposium on Internal Stresses in Metals and Alloys, Institute of Metals, London, 1948, p. 477.
11. J. J. Heger. Stress Corrosion of Stainless Steel. *Metal Progress,* **67,** 109 (1955) March.
12. H. Bennek. Spannungskorrosionsercheineingen bei Eisenlegierungen. *Korrosion u Metalluschutz,* **20,** 133 (1944).
13. O. B. Ellis. Some Examples of Stress Corrosion Cracking of Austenitic Stainless Steel. Symposium on Stress Corrosion Cracking of Metals, published by ASTM and AIMME, Philadelphia and New York, 1945.
14. F. W. Davis. Discussion in Symposium on Stress Corrosion Cracking of Metals, published by ASTM and AIMME, Philadelphia and New York, 1945, p. 429.
15. F. W. Davis. Stress-Corrosion in a Stainless Steel Compressor. *Trans. Am. Soc. Metals,* **42,** 1233 (1950).
16. J. A. Collins. Effect of Design, Fabrication, and Installation on the Performance of Stainless Steel Equipment. *Corrosion,* **11,** 27 (1955).
17. C. Edeleanu. The Phenomena of Stress Corrosion Cracking in Austenitic Stainless Steels. Stress Corrosion Cracking and Embrittlement, John Wiley and Sons, New York, 1956.
18. W. L. Williams and J. F. Eckel. Stress Corrosion of Austenitic Stainless Steels in High Temperature Water. *J. Am. Soc. Naval Eng.,* **68,** No. 1, 93 (1956).
19. A. W. Dana and W. B. DeLong. Stress Corrosion Cracking Test. *Corrosion,* **12,** 19 (1956).
20. H. L. Logan and R. J. Sherman. Stress-Corrosion Cracking of Type 304 Austenitic Stainless Steel. *Welding J.,* **35,** 389s (1956).
21. H. R. Copson. Laboratory Techniques for the Investigation of Stress Corrosion Cracking. Stress Corrosion Cracking and Embrittlement, John Wiley and Sons, New York, 1956.
22. R. A. Lincoln. Stress Corrosion in Stainless Steel. Yearbook Am. Iron Steel Inst., p. 172 (1954).
23. H. R. Copson. Corrosion Handbook, John Wiley & Sons, New York, 1948, p. 571.
24. H. R. Copson. The Influence of Corrosion in the Cracking of Pressure Vessels. *Welding J.,* **32,** 75s (1953).
25. H. J. Rocha. Zur Spannungskorrosion Austenitischer Stahle. *Tech. Mitt. Krupp Forschungsber,* **5,** 1 (1942).
26. H. J. Rocha. Die Spannungskorrosion Austenitischer Stahle. *Stahle u Eisen,* **62,** 1090 (1942).
27. H. Thielsch. Physical Metallurgy of Austenitic Stainless Steels. *Welding J.,* **29,** 577s (1950).
28. C. Edeleanu. Discussion. *J. Iron and Steel Inst.,* **175,** 390 (1953).
29. Unpublished data, International Nickel Co., Inc.

Any discussions of this article not published above will appear in the December, 1957 issue.

A Corrosion Problem in Large Steam Generating Stations★

By T. J. FINNEGAN

Introduction

INTERNAL CORROSION of boiler tube surfaces is an extremely serious matter in modern large steam generating stations. It strikes at the very heart of the power generation process and thus can cause power units in excess of 100,000 kilowatts to be forced out of service with little or no advance warning.

Before proceeding further it might be well to consider briefly the nature of the steam condensate cycle of a modern single boiler-single turbine unit. Figure 1 shows a typical steam generating cycle. Steam enters the turbine at 1450 psig and 1000 F. It leaves the high pressure section at about 430 psi and is lead back to the reheater inside the boiler casing where its temperature is again raised to 1000 F. It then passes through the intermediate and low pressure sections of the turbine to the condenser from which it is pumped through the feedwater heaters back to the boiler. The heaters are heated with steam extracted from the turbine.

Figure 2 is a cross section of a typical boiler showing the location of some tube failures. From the pulverized coal burners the hot gases pass through the primary furnace and the large secondary furnace. From there they go through the superheater, the reheater, the economizer, the air heater, the dust collectors and the induced draft fans to the stack. On passage from the primary to the secondary furnace the gas passes through the bank of screen tubes. It is in this bank that some failures have occurred.

Figure 3 shows the "open-pass design" type of boiler. Instead of the large secondary furnace there are two open passes through which the combustion gas flows on its way out of the boiler. Tube failures have been found at the points indicated, namely, at the screen and in the roof tubes at the top of the second open pass.

The two boilers shown are of wet bottom type (i.e., boilers on which a large part of the ash is removed as a molten slag). Some corrosion also has been experienced in a dry bottom boiler such as illustrated in Figure 4. The leak occurred in one of the arch tubes below the pendant superheater where the tubes are almost horizontal.

These boilers happen to be the type in which this corrosion has occurred in the Niagara Mohawk system. Other companies with other boiler designs also have experienced it.

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Abstract

Internal corrosion of boiler tube surfaces is a serious problem in the electric utility industry. Such corrosion usually takes the form of a pinhole leak which at first does not affect the boiler operation or attract the attention of the operator in the control room. The pinhole increases in size until it is large enough to cause the tube to be torn apart.

Heavy deposits of a black oxide frequently are found in a tube at or near the point of failure. Possible explanations for the presence of this oxide are: (1) Iron removed from the piping and equipment in the pre-boiler circuit may be carried back into boiler when the oxygen-free alkaline environment favors its precipitation as black iron oxide (Fe_3O_4), and (2) Some factors may prevent the formation of the protective film which is needed to prevent bare metal from coming in contact with water. Protective measures based on both premises were put into use.

One method of combatting this type of corrosion involves the maintenance of an optimum concentration of "free caustic" in the boiler water. Another method is to clean the boiler periodically with low strength hydrochloric acid. Many boiler operators found it helpful to make the condensate alkaline in order to protect pre-boiler equipment. Cyclohexylamine, morpholine and ammonia were used in this connection. Although favorable results were reported in many cases there is still some lack of agreement about the effectiveness of such compounds. **7.6.4**

Manifestations of Failure

Failure usually starts as a tiny pinhole leak which does not affect the boiler operation and is not observed by the operators in the control room. Individuals in the laboratory notice, however, that there is a steady drop in the dissolved solid content of

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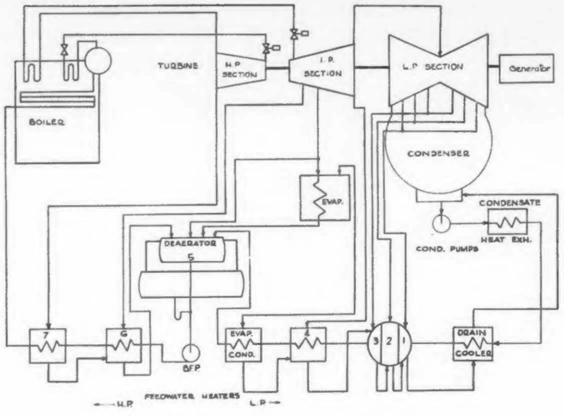


Figure 1—Typical steam generating cycle.

the boiler water as the leak discharges water into the furnace and the feed water controls draw from the condensate storage to maintain the boiler water level.

The initial pinhole will increase in size as the weakened tube wall cannot stand the stress imposed and suddenly the tube will be torn apart, spouting water into the furnace with 1000 to 3000 pounds pressure behind it. Damage to neighboring tubes may occur and the carefully designed circulation pattern of the boiler will be disturbed.

Possible Causes of Failures

The typical appearance of the corrosive failure is shown in Figure 5. It takes the form of a pit, the center of which contains a lump of Fe_3O_4. The appearance of these deposits has led the power plant men to call them "scabs." Like scabs they can be dislodged to reveal the open pit although sometimes it is necessary to use an air chisel to accomplish this. These pits are the results of corrosion cells but the electrolytic action is not simple or obvious.

Elements of a concentration cell exist where boiler water trapped beneath a spot of black iron oxide concentrates and there are also the elements of a dissimilar electrode cell where Fe_3O_4 and iron are together in the concentrated boiler water.

Dissolved oxygen also has been blamed for the failure. Although the feedwater entering a modern boiler contains nominally "zero oxygen" and by the best analytical method only shows a few thousandths of a ppm with the boiler on full load, oxygen concentrations high enough to be objectionable may be found during low load periods. Week ends usually are low load periods and much of the condensate circuit may be under vacuum and the venting of the deaerating heater may be inadequate because of high steam specific volume. Oxygen recorders have been used to reveal this condition. Also, the oxygen entering the boiler during the filling and when coming on the line when the deaerator fails to deaerate completely, is released as the water is brought up to pressure. The bubbles may be trapped at parts of high heat input where the elements of the cell described aggravate its action.[1]

Inasmuch as the black magnetic oxide seems to be an important factor in the formation of pits, some consideration might be given to its role in the boiler. First, it should be noted that when iron and water are in contact in the absence of complicating factors such as dissolved oxygen the stable solid phase is Fe_3O_4. It is, therefore, physically and chemically impossible to maintain a metallic iron surface in contact with the boiler water, and all boilers of the type under consideration have a thin, dense coating of Fe_3O_4. It is in the nature of a stain, practically integral with the tube surface.

On occasion loose powdery black iron oxide is seen. When a boiler is opened for inspection varying amounts of this substance are found in the drums, especially the lower drum. It also is found in some of the tubes, especially those that are not vertical. It is probable that the black surface of the tube is a normal condition for the interior of a boiler and the loose deposit is produced by some extraneous cause.

Frequently when a tube has failed because of corrosion, heavy deposits of black oxide are found at and near the point of failure while a short distance away the metal has a surface typical of a boiler in good condition. It would seem that the oxide deposit may in some way start the corrosion and also that it may result from it.

This would suggest that if all the black oxide in the boiler were of the tightly adherent type and none of it were present as a loose powder or sludge, an important factor in this type of corrosion would be eliminated. It will be noticed that all the failures in the boilers shown in Figures 2, 3 and 4 occurred where the tube was at an angle, suggesting that loose oxide traveling through the boiler circuits collected in these sloping tubes and started the mechanism of pit formation.

As to the source of the black oxide sludge, there are two possibilities: (1) some factor may either prevent the formation of the adherent tight protective film or cause it to lose its protective characteristics, thus exposing the bare metal which reacts with the water to produce Fe_3O_4 and, (2) iron removed from the piping and equipment in the preboiler circuit may be carried into the boiler where the oxygen-free alkaline environment favors its precipitation as black iron oxide Fe_3O_4. This may occur at all times but especially when the unit is first put in operation and the heaters, pumps and piping become subject to a new environment, namely, essentially oxygen-free condensate with which the metal surface must come into equilibrium. Eventually, a smooth oxide coat is obtained but in the meantime much of the original scale is removed and carried into the boiler, which acts as a sump. Some of this deposit may be in a form which lets it collect readily on sloping boiler tubes.

Protective Measures

Protective measures based on both of the above mentioned premises are in use. One method is by maintaining an optimum concentration of "free caustic" in the boiler water. Unfortunately, it is not known (a) what is the optimum concentration of

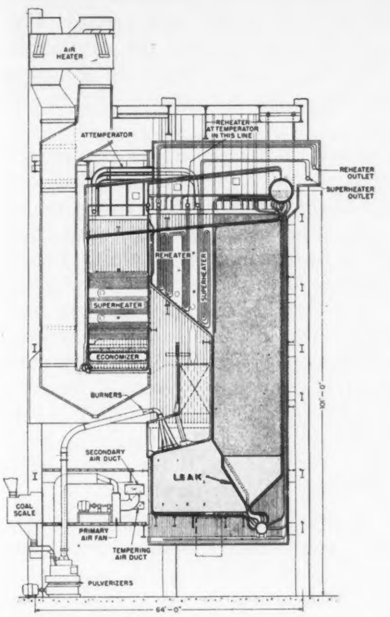


Figure 2—Radiant boiler slag tap ash removal (Drawing courtesy of The Babcock & Wilcox Company).

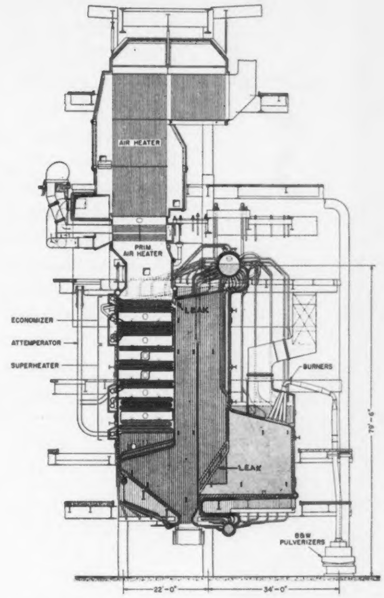


Figure 3—Open pass boiler slag tap ash removal (Drawing courtesy of The Babcock & Wilcox Company).

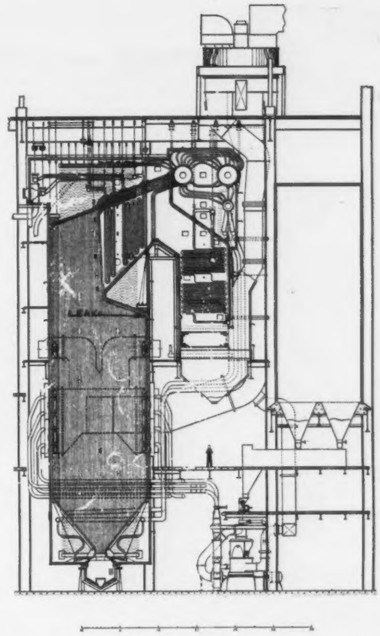


Figure 4—C. E. boiler dry ash removal (Drawing courtesy of Combustion Engineering, Inc.).

free hydroxide in the film of water adjacent to the tube to maintain a protective coating and (b) what the concentration of free hydroxide should be in the bulk of the boiler water to maintain this optimum concentration against the tubes. It should be realized that the concentration of dissolved material in the layer of water adjacent to the metal of a steaming tube is higher than that found in a routine sample drawn from the bulk of the boiler water.

Some recent laboratory studies have indicated that a concentration of about 700 ppm NaOH against the metal is necessary to produce an adherent protective film.[2]

On the premise that when internal pitting occurs there might not be sufficient free hydroxide in the boiler water to ensure that the optimum amount is present adjacent to the tube wall, it sometimes has been recommended that the free hydroxide be increased when boilers operating with a low concentration have had tube corrosion. For instance, some boilers with which the writer is acquainted have operated with about 6 ppm free hydroxide and have had some tube losses. Recently the concentration has been doubled with the thought that it may help to increase the concentration of hydroxide at the tube surface.

If free hydroxide is beneficial in producing a protective surface the question arises as to why a substantial dose of it could not be added to the boiler water to make certain that an adequate amount is adjacent to the tube wall. The answer is that too much free caustic may aggravate the attack of the steel. A complete explanation would be unduly complex and involve physico-chemical theory.[3] It will suffice to say that when a solution of free hydroxide is heated in a confined space such as beneath a particle of scale an extremely high concentration approaching the state of molten sodium hydroxide is produced. This results in something similar to the fusion process which is used in the laboratory to dissolve difficultly soluble metal oxides and the bare metal becomes exposed and corrosion continues.

There are certain individuals who consider "free caustic" to be objectionable for the reason just given and who obtain the desired hydroxide ion concentration or pH value of the boiler water from some other source that does not involve the risk of concentrating caustic solutions. Specifically, they obtain it from the hydrolysis of phosphate.[4] Presumably, the advocates of this method do not accept the theory of the stabilizing action of free hydroxide.

One characteristic of this type of control is that it gives a considerably higher solids content of the water than results from the low free-hydroxide treatment. Some object to it on this basis.

The advocates of free-hydroxide will reply that its excess in the boiler water must be carefully controlled and correlated with experience and the inspection of tube sections. In other words, if a boiler carrying 6 ppm of free OH loses tubes the concentration might be raised to, say 10 ppm, and observations made as to whether or not corrosion decreases.

It would be an advantage if it were definitely known if the optimum free hydroxide is zero or some variable depending upon boiler design and operating conditions. As a matter of fact, there is a lack of fundamental information on iron-water chemistry, especially at high temperatures.

Black Iron Oxide

The black iron oxide which originates in the preboiler equipment may next be considered. There are

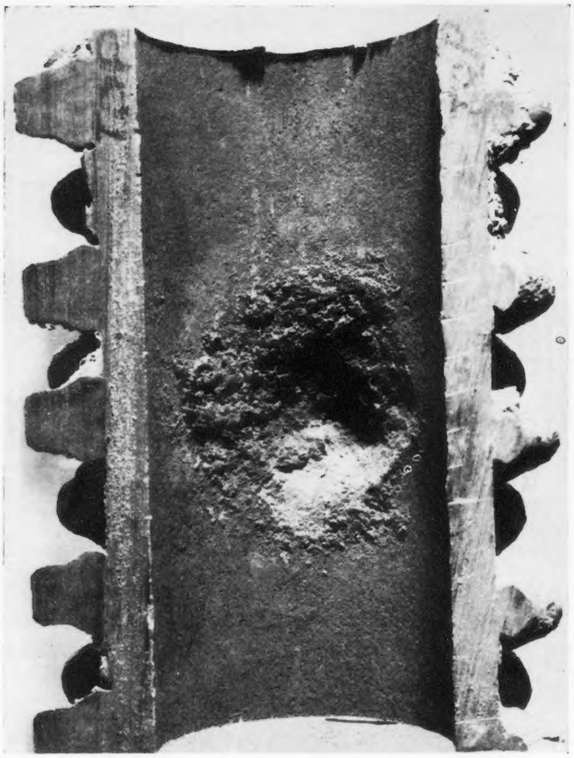


Figure 5—Characteristic tube corrosion (Photo courtesy of Hall Laboratories, Inc.).

two sources of this material. The first is the mill scale of Fe_3O_4 produced in the fabrication of the equipment and it is more or less affected by the atmosphere during the time the equipment is being installed. Another probable source of Fe_3O_4 is regular attack of the pre-boiler piping and other equipment by the condensate. When condensate forms in the turbine and condenser it presumably has a pH value of approximately 7.0, depending upon the temperature. Immediately on coming in contact with the steel, ferrous ions go into solution displacing hydrogen until the limit of iron solubility is reached. The pH increases to about 8.0-8.3. Unfortunately, the stable solid phase of this equilibrium is the black oxide Fe_3O_4 which precipitates iron from solution permitting the water to dissolve more iron to maintain equilibrium. The oxide formed is carried into the boiler.

The collection of iron oxide in the boiler during the early days of its operation has led to the adoption of the practice among many boiler operators of acid cleaning the boiler after a short period of operation. Leading boiler manufacturers support this practice. Fe_3O_4 is only slightly attacked by the low strength hydrochloric acid used (about 5-10 percent at a maximum temperature of 175 F) but there appears to be sufficient attack to loosen it so that it may be washed from the boiler.

Certain individuals advocate periodic acid cleaning of the boiler, the frequency either arbitrarily set as once a year or once every two years, etc., or determined by the removal and examination of a section from a critical part of the tube circuit. The advocates of this practice believe that the iron oxide produced in day by day service must be guarded against as well as that collected during the initial period of operation.

To combat the attack of the pre-boiler equipment by condensate and perhaps incidentally to eliminate the necessity of all but the initial acid cleaning, many boiler operators are now making the condensate alkaline. This is not a new principle. Chemicals such as trisodiumphosphate have been added to condensate systems of older boilers in the past and recirculation of boiler water back to the deaerator or lower in the cycle has been discussed among power station chemists and engineers for years. The first of these practices increases the boiler water solids and the second is difficult to control, making both of them unattractive for use in the modern high pressure system. Instead, volatile bases are used.

Ammonia is added in some cases but the chemicals most generally used are cyclohexylamine and morpholine. These materials are added to the condensate with which they are carried into the boiler, volatilizing with the steam, dissolving in the condensate and repeating the circuit. Obviously, a desirable attribute is a distribution between the liquid and vapor phases such that a large concentration is present in the liquid. This lessens the risk of its removal from the system by the air removal equipment and makes continuous feed of the reagent less necessary. Morpholine came into use because of its superior distribution characteristics. A sufficient quantity of the base is added to give the condensate a pH of 8.5-9.0 at which hydrogen ion concentration only a few thousandths of a ppm of iron ordinarily are dissolved.

The use of these organic bases has been adopted by many power plants with generally favorable reports of results, including some cases where there was not only a reduction of the iron content of the condensate but of the copper as well. Because of their relationship to ammonia there is some reluctance to accept them unreservedly and occasionally one hears of an increase in copper pick-up which is blamed on the use of amines.

In favor of the use of organic bases is the successful application of ammonia itself for the purpose. The freedom from corrosion of copper and nickel is attributed to the fact that oxygen is necessary in order to form the metal ammonium complex which is the corrosion product and the oxygen content of the condensate is too low, usually of the order of parts per billion. As a matter of fact, the only water treatment planned for the new supercritical pressure boilers which are under construction is ammonia. In these boilers operating at 5000 pounds pressure or thereabouts there is no sharp distinction between water and steam. The fluid flows once through the boiler entering as water at one end of the tube and leaving as steam at the other. Leaving any solid residue would be objectionable. Ammonia has been used for the once-through Benson boilers in Europe for many years.

This lack of complete agreement on the efficacy

of amino compounds illustrates that there is a need for fundamental chemical studies of their behavior with nonferrous metals. Research should be undertaken to determine: (1) how much oxygen is necessary for the copper ammonium and nickel ammonium complexes to form or conversely, how low must oxygen be in a condensate system to avoid corrosion by ammonia and, (2) to what degree do amines, especially those used in water conditioning behave analogously to ammonia and what are the quantitative significances of the physical and chemical factors such as vapor pressure, temperature, oxygen content, presence of catalysts, etc.

Conclusion

A particular type of corrosion which is a matter of great concern to the power industry has been described. Some of the methods which have been used to combat this type of corrosion have been outlined. If a plea is made in this paper for more research of a fundamental nature, it is not intended to show a lack of appreciation of all those practical preventive measures which have been developed on the basis of our present knowledge and experience. These measures have made it possible to operate the modern steam generators with their extremely high rate of dependability.

Much of this work has been done by the members of the Chemistry Subcommittee of the Prime Movers Committee of the Edison Electric Institute both as individuals and as a group and credit must be given to this organization which is little known outside of the power industry. Others to whom credit is due are the consultants in the field of boiler water technology and the research and service personnel of the boiler manufacturers.

References

1. H. A. Grabowski. *Trans. ASME*, **77**, 433 (1955)
2. E. P. Partridge & R. E. Hall. *Trans. ASME*, **61**, 597 (1939)
3. R. E. Hall. *Trans. ASME*, **66**, 457 (1944)
4. S. F. Whirl (Discussion of Reference 3). *Trans. ASME*, **66**, 485 (1955)

DISCUSSION

Question by H. T. Smith, Electro Metallurgical Company, Niagara Falls, New York:

Would you care to comment on the use of Hydrazine as an oxygen scavenger and to improve pH in the feedwater part of the cycle?

Would you care to comment on Sheppard T. Powell's hypothesis that Fe_3O_4 can be due to mill scale included in tubes during manufacture?

Reply by T. J. Finnegan:

Hydrazine is an attractive oxygen scavenger because the products of its reaction with oxygen are nitrogen and water. There is, however, some disagreement on its effectiveness. Certain individuals claim it is successful in reducing oxygen while others consider it ineffective unless the reaction is catalyzed. It apparently has a slow reaction rate at the temperatures existing in the low pressure portion of the cycle and it decomposes to ammonia at the temperatures approaching that of the boiler. We have studied it to a limited degree with feedwater conditioning considerably less than 0.01 ppm oxygen and have not found evidence that it would remove these low concentrations. It might be more reactive with higher oxygen concentrations.

It is common practice to remove the mill scale from boiler tubes before operation. Some companies specify pickling in the shop and some acid clean the boiler after erection. Some do a combination of both. It also is believed that much of the iron oxide sludge that results in boiler corrosion has its origin in the piping and other equipment of the feedwater circuit. Organic bases are being used to raise the pH of the feedwater and some companies today are acid cleaning the piping to remove as much of the mill scale as possible. The normal surface for good operation is a very thin completely adherent film of Fe_3O_4.

Any discussions of this article not published above will appear in the December, 1957 issue.

Shipboard Evaluation of Zinc Galvanic Anodes Showing the Effect Of Iron, Aluminum and Cadmium on Anode Performance★

By E. C. REICHARD and T. J. LENNOX, JR.

EDMUND C. REICHARD is an independent consultant on corrosion problems working from Holmdel, N. J. The work described in this paper was completed while he was group leader for work on corrosion at the Central Research Laboratories of the American Smelting and Refining Company, South Plainfield, N. J. His employment with the research laboratories of ASARCO extended over a period of ten years, following active duty in the Navy and prior employment with Phelps Dodge Copper Products Corporation, Picatinny and Frankford Arsenals. He is a graduate of the School of Engineering, Columbia University, and is active in NACE, ASM and AIME.

T. J. LENNOX, JR. is a corrosion engineer, specializing in cathodic protection, with the American Smelting and Refining Company at the Central Research Laboratory, South Plainfield, N. J. From 1950 to 1953 he did polarographic research for J. T. Baker Chemical Company, Phillipsburg, N. J. In 1949 he received a BS in chemistry from Wagner College, Staten Island, New York. During World War II he served as a Marine fighter pilot in the Pacific. Mr. Lennox is a member of NACE, ACS and RESA.

Abstract

A commercial zinc anode with desirable long term galvanic performance characteristics has been developed. Aluminum plus cadmium added to zinc has produced this improved anode.

The tolerance for iron in zinc anodes has been increased by the aluminum plus cadmium addition. Less adherent corrosion products and uniform anode attrition also have been achieved without adverse effects on anode current efficiency. Improved zinc anode performance obtained with the aluminum plus cadmium addition is independent of anode current density or electrolyte temperature.

In the absence of other constituents, controlling the iron content at 0.0014 percent does not give a zinc anode with optimum galvanic properties. Best performance is obtained when the iron content is on the order of 0.0002 percent.

Barrier shields serve no useful purpose on the faying surface of zinc anodes installed on steel ship hulls.

Long term performance tests on five active ships and quiescent marine exposures, using commercial size zinc anodes, provide the basis for these conclusions. **5.2.2**

Introduction

THE AMERICAN Smelting and Refining Company (ASARCO) has conducted an extensive research program studying the effect of composition on zinc anodes. Commercial size zinc anodes were extensively used in these tests.

This work supplements that done under the auspices and sponsorship of the American Zinc Institute. The latter work was conducted at the Harbor Island Test Station of the International Nickel Company and was reported in a paper published by Teel and Anderson.[1] Zinc specimens measuring 2⅜ x 3⅞ x ½ inch were evaluated in a 30 day test. A maximum iron limit of 0.0015 percent in zinc anodes was indicated. The Navy has since adopted a 0.0014 percent iron limit for zinc anodes.[2]

ASARCO work initially involved small size anodes, duplicating test procedures previously employed.[1] These tests were conducted in order to explore the effect of test location. The agreement of results obtained at the ASARCO Marine Test Station with those obtained in Central Atlantic coastal waters indicated that test location was not a critical factor.

The effect of iron was then studied at the ASARCO Marine Test Station, using a 6 x 5½ x ¾ inch (half size) zinc anode specimen. Results from these tests showed that iron was consistently detrimental to the performance of zinc anodes (Figure 1). The detrimental effect was almost in direct proportion to the iron content.

Because of the inability to verify work of other investigators, and in order to obtain data that would be valid for the commercial product, a 6 x 12 x 1¼ inch, 24 pound zinc anode specimen was used for all subsequent work. This anode is identical in size to those offered the marine trade by the Federated Metals Division of American Smelting and Refining Company and other producing companies.

Exposure Conditions

Active Ship Tests

Five active ships of both tanker and ocean licensed tug classification were chosen for this work. The selection was made on the basis of their size and type of service.

The location and arrangement of anodes were intentionally varied on each test hull. The anodes were fastened with lock nuts to studs welded to the hull of the test vessel. Anodes both with and without a barrier shield on the set surface were exposed in order to evaluate the effectiveness of this item. The test periods, determined by operating schedules were 9, 12 and 15 months for the T-2 Tanker, Tugs and Navy YO Class Tanker, respectively.

Anode current output was calculated from weight loss. Ninety percent anode current efficiency was assumed in these calculations.

★ Submitted for publication September 10, 1956.

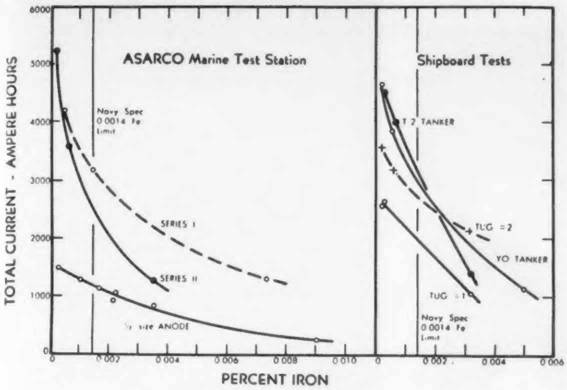


Figure 1—Effect of iron on commercial size zinc anodes.

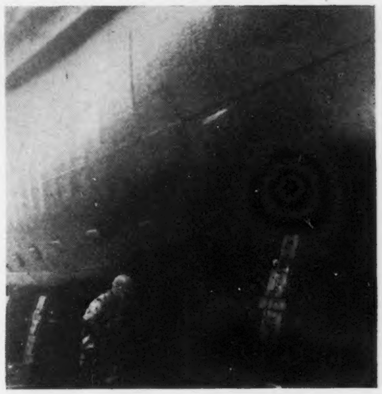


Figure 2—Installation of anodes on Tug No. 1.

Typical port side views of the zinc anode installations on active ships are shown in Figures 2, 3 and 4.

ASARCO Marine Test Station

An extensive, electrically continuous, steel bulkhead was used as the cathode in this work. This bulkhead is the retaining wall for a small boat basin located on an inlet less than one mile from the Atlantic Ocean, along the north Jersey shore.

The inlet water is free of industrial pollution. Ocean water, including full tidal effects, constitutes the exposure medium.

Two series of anodes, cast at different times, were exposed. One set was exposed with an asphalt barrier shield cast over the set surface, while the other set was exposed without this shield.

The anodes were hung at twenty foot intervals, four feet from the bulkhead, under a wooden dock that extended six feet out over the water from the bulkhead. The flat 6 x 12 inch anode surfaces paralleled the extensive steel cathode.

Number twelve TW copper wire was soldered to the projecting ends of each anode core. These lead wires were connected through a 0.1 ohm current measuring shunt to the steel bulkhead.

An aerial view of the Marine Test Station is shown in Figure 5. The outline of the steel bulkhead has been emphasized.

Data and Discussion

Effect of Iron

Total current output data obtained from commercial size zinc anodes installed on four different active ships and two series of exposures in quiescent water at the Marine Test Station are shown in Figure 1. These test results were in very close agreement. They show that iron is consistently detrimental to zinc anode performance. The most effective zinc anode, in the absence of other constituents, is one that contains essentially no iron (0.0002 percent).

In contrast, Teel and Anderson concluded that 0.0015 percent iron was not detrimental to zinc anode performance. The ASARCO commercial size anode tests show that results obtained with small size anode specimens cannot be applied to the commercial product.

Commercial size zinc anode tests showed that optimum anode performance, in the absence of other constituents, is obtained at extremely low (0.0002 percent) iron levels. Zinc anodes of this composition are not commercially available. The need for further work studying effects of composition was, therefore, definitely indicated. The use of commercial size zinc anode specimens in this work is mandatory in order to obtain valid conclusions.

Typical photographs of commercial size zinc anodes with varying iron contents are shown in Figure 6. In all of this and subsequent work reported, Special High Grade Zinc was used, except as noted for special additions.

Effect of Aluminum Plus Cadmium

Nominal levels of 0.1 percent aluminum plus 0.05 percent cadmium added to zinc anodes, results in a commercial product that has desirable long term galvanic properties. The detrimental effect of iron has been eliminated at all iron levels studied. Effect of other aluminum plus cadmium levels on zinc anode performance is now being investigated to define optimum limits.

Total Current. Total current output values obtained for zinc anodes containing aluminum plus cadmium are shown in Figure 7. These data show the detrimental iron effect was eliminated up to levels approaching 0.004 percent. The beneficial effect of the aluminum plus cadmium addition was confirmed in both shipboard tests and in the quiescent exposure conditions at the Marine Test Station.

The control anode used in this work contained 0.0002 percent iron, which is far below that commercially available. Figure 1 shows the significantly lower total current output values obtained from zinc anodes with iron levels approaching 0.001 percent. The beneficial effects obtained from the aluminum plus cadmium addition are, therefore, even greater when compared to zinc anodes that are currently available.

Current Output Versus Time Characteristics. The dependability of a galvanic anode to continually produce current is of primary importance. Anode current output versus time characteristics must, therefore, be considered in addition to the total current produced.

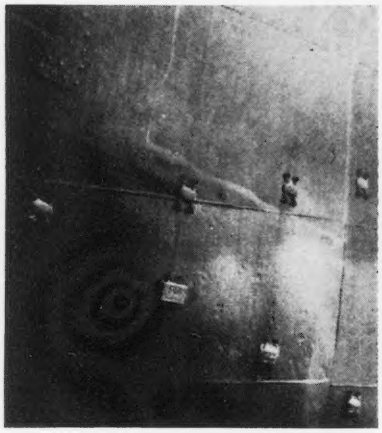
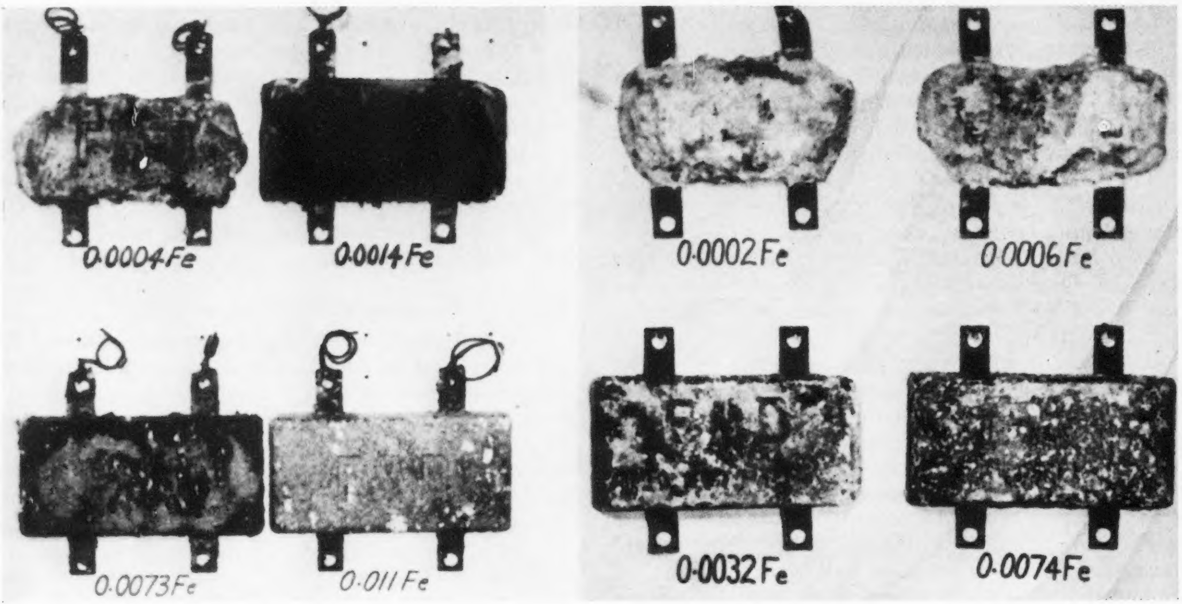


Figure 3—Installation of anodes on T-2 Tanker.

Figure 4—Installation of anodes on Navy YO Class Tanker.

Figure 5—ASARCO Marine Test Station.



ASARCO Marine Test Station
1 Year Exposure

T-2 Tanker
9 Month Exposure

Figure 6—Effect of iron on anodes (before cleaning).

Current output values of all anodes tested at the Marine Test Station were measured weekly. The relative current outputs of zinc anodes containing aluminum plus cadmium, compared to a low iron (0.0002 percent) control anode, are plotted on a monthly basis in Figure 8. These data also emphasize the beneficial effects obtained by adding aluminum plus cadmium to zinc anodes.

Anode Current Efficiency. Greater than 90 percent galvanic efficiency was calculated for all the zinc anodes containing aluminum plus cadmium tested at the Marine Test Station. These efficiencies are comparable to those obtained with the 0.0002 percent iron content control. The aluminum plus cadmium addition, therefore, has no adverse effect on zinc anode galvanic efficiency.

Anode Current Density Effects. In the active ship tests, anode current density varied in accordance with the ship type, size, speed and hull paint condition. The average current output produced per anode was calculated from the weight loss; from this figure, the average anode current density was determined. Values obtained for the low iron control anodes were as follows:

Ship Classification	Average Anode Current Density
Tug No. 1	345 ma/sq ft
Tugs No. 2 and 3	485 ma/sq ft
Navy YO Tanker	515 ma/sq ft
T-2 Tanker	840 ma/sq ft

The current densities also were intentionally varied in the quiescent Marine tests. This was achieved by installing one series without, and a second with an asphalt

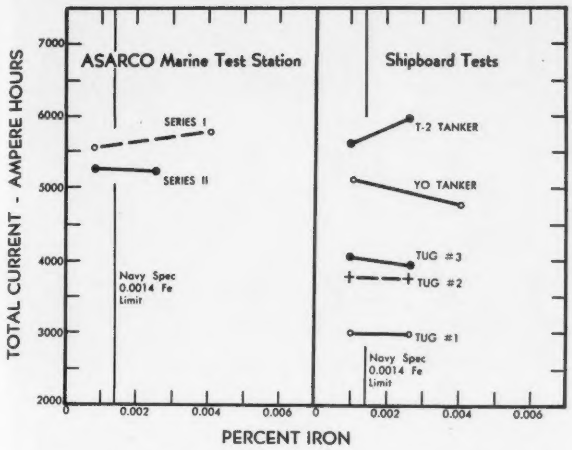


Figure 7—Effect of 0.1 percent aluminum plus 0.05 percent cadmium at various iron levels—commercial size zinc anodes.

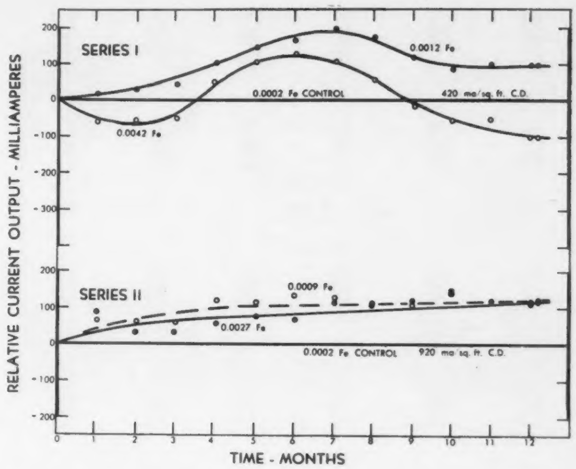


Figure 8—Performance of commercial size zinc anodes containing 0.1 percent aluminum plus 0.05 percent cadmium.

TABLE 1—Initial Current Densities of Two Anodes

	Nominal Weight Pounds	Initial Current MA	Initial Current Density MA per Sq. Ft.
22.2 Sq In Area Anode (2¾x3⅞x½″).....	1	430	2800
Commercial Size Zinc Anode (6x12x1¼″)..	24	550	420

barrier, masking off one 6 x 12 inch surface of the freely hung anode. As the currents were measured throughout these tests, it was possible to show actual initial anode current densities. The values obtained with the low iron controls were:

	Initial Anode Current Density
Series 1 (Without asphalt barrier)	420 ma/sq ft
Series 2 (With asphalt barrier)	920 ma/sq ft

Total current output data in Figure 7 and current output versus time curves Figure 8, show that the improved zinc anode performance obtained with the aluminum plus cadmium addition was independent of anode current density. Similar effects were observed in both the shipboard tests and quiescent exposures at the Marine Test Station.

Temperature Effects. All of the vessels used in the shipboard evaluation tests were drydocked at New York Harbor shipyards. The anodes were installed as follows:

Ship Classification	Month Installed
Navy YO Tanker	January
T-2 Tanker and Tug No. 1	April
Tug No. 2	May
Tug No. 3	June

Anodes in Series 2 were exposed at the Marine Test Station 52 days after the anodes in Series 1 (See Figure 7).

The close correlation of all results, in spite of varying installation times, exposure conditions and temperature cycles, rules out temperature as a significant factor.

Anode Solution Potential and Corrosion Characteristics. The addition of aluminum plus cadmium to zinc does not alter the anode's solution potential. Initial current output from anodes of this composition is similar to that obtained from anodes made with 0.0002 percent iron, Special High Grade Zinc.

The aluminum plus cadmium addition, however, eliminates the development of adherent corrosion product films on zinc anode surfaces. Anodes of this composition, therefore, have level current output characteristics as contrasted to the fall off in current output with time that occurs with the present commercial product. Total current output produced over a given time period is, therefore, greater with the zinc anodes containing aluminum plus cadmium.

The corrosion pattern of low iron content-Special High Grade Zinc anodes is generally very irregular. Widely spaced, very deep pits develop on some anode surfaces, while other anode areas are essentially inactive. This is caused by differences in corrosion product adherence. Galvanic anodes that are consumed in such an irregular fashion cannot be depended on for satisfactory long term service performance.

The addition of aluminum plus cadmium to zinc produces an anode with a very desirable corrosion pattern. All major flat surfaces and edges are uniformly active. This characteristic is valuable because all surfaces of the anode are producing current and long term satisfactory performance has been obtained.

A typical set of photographs showing differences in anode corrosion characteristics are shown in Figures 9 and 10.

Intergranular Corrosion. Intergranular corrosion of zinc is detrimental in most applications. In aluminum containing zinc base die casting alloys, intergranular corrosion occurs when lead or cadmium are present. This is especially serious in thin section

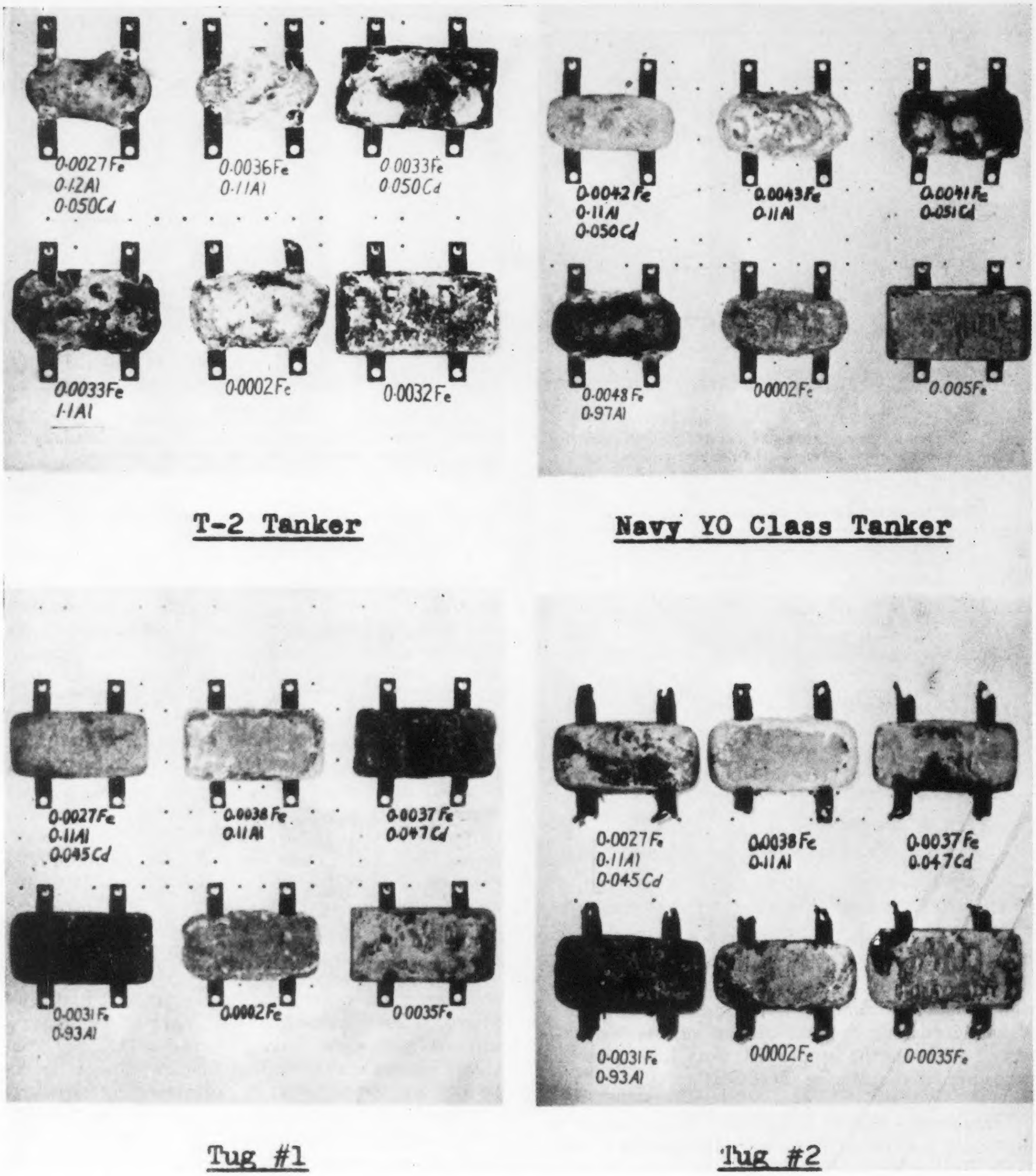


Figure 9—Shipboard Tests—Appearance of commercial size zinc anodes as removed from ships. Exposure time was 9-15 months.

castings depended upon for structural properties. In contrast, zinc when used as a galvanic anode is a massive casting whose sole purpose is to provide a source of current.

Zinc alloys containing aluminum plus cadmium have been exposed to steam tests. Some intergranular corrosion was observed after 288 hours. On the other hand, zinc anodes containing aluminum plus cadmium have been exposed to high temperatures and relative humidities for extended periods without adverse effects. Galvanic efficiencies of all anodes containing aluminum plus cadmium have been determined to be greater than 90 percent.

On the basis of the high anode galvanic efficiency and lack of adverse effects in the high temperature-relative humidity tests, it is concluded that intergranular corrosion will not be a detrimental factor with zinc anodes containing aluminum plus cadmium.

Effect of Aluminum or Cadmium Added Singly

Neither aluminum nor cadmium added singly eliminates the need of controlling the iron content of zinc

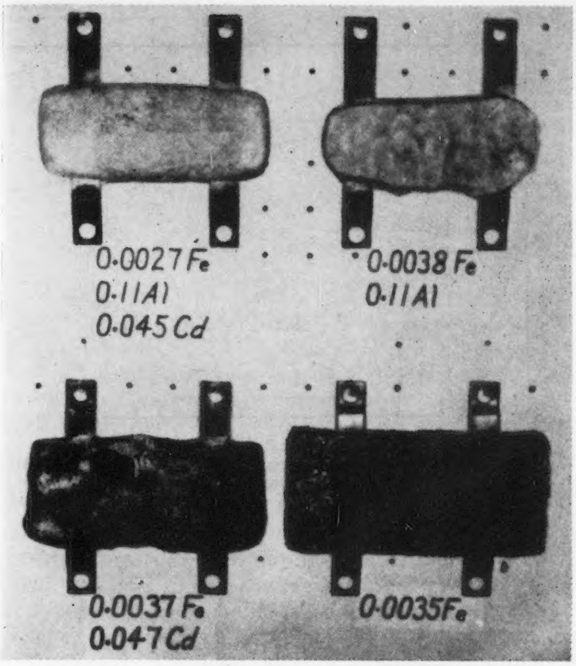


Figure 10—ASARCO Marine Tests—Appearance of commercial size zinc anodes after cleaning. Anodes were exposed 12 months under quiescent conditions.

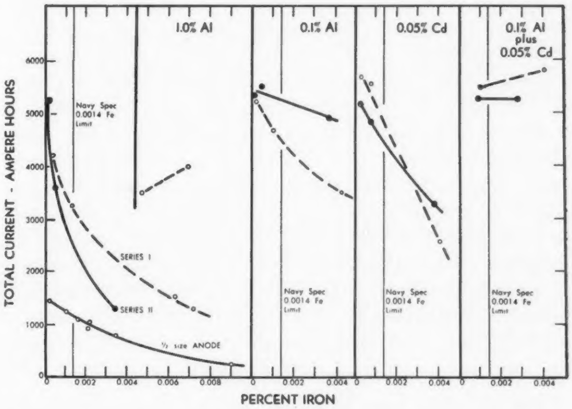


Figure 11—Effect of iron, aluminum and cadmium on zinc anodes (twelve month exposure period at the ASARCO Marine Test Station.)

anodes at very low values. This is especially evident in the total current output versus iron content curves shown in Figure 11. In contrast, the shipboard test results, summarized in Figure 12, show singular additions of aluminum or cadmium are beneficial. This is attributed to velocity effects.

The relative current output versus time plottings also show the need for controlling iron at extremely low values when aluminum is added singly to zinc anodes (Figures 13 and 14). A similar plot was obtained for anodes containing cadmium singly, but is not shown because of space limitations.

Performance of zinc anodes containing singular additions of aluminum or cadmium is dependent on anode current density (Figures 11, 12 and 13). Aluminum or cadmium added singly are less effective in

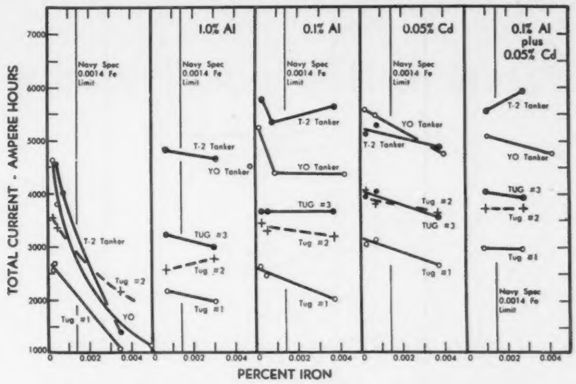


Figure 12—Effect of iron, aluminum and cadmium on zinc anodes.

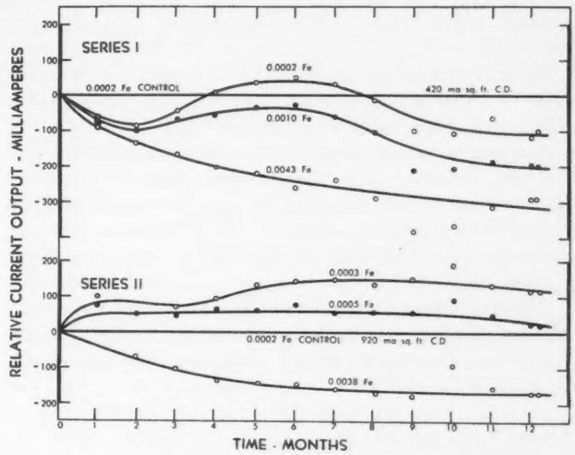


Figure 13—Performance of commercial size zinc anodes containing 0.1 percent aluminum.

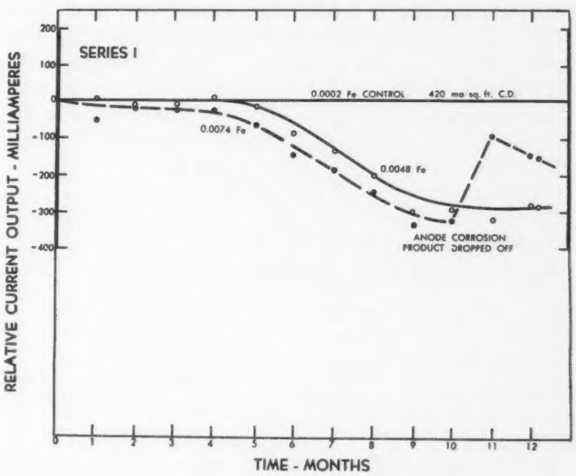


Figure 14—Performance of commercial size zinc anodes containing 1.0 percent aluminum.

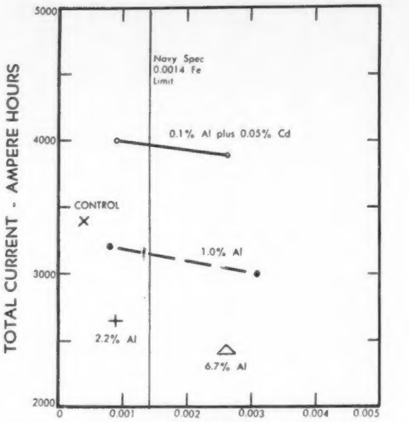


Figure 15—Effect of aluminum on iron in commercial size zinc anodes.

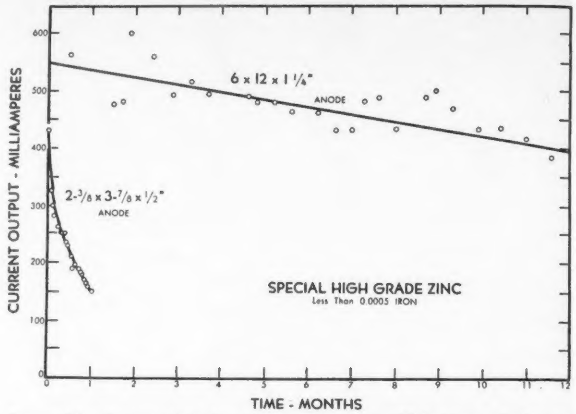


Figure 16—Commercial size zinc anode versus 22.2 square inch area test anode.

eliminating the detrimental effect of iron on zinc anodes when the anode operates at low current densities.

Aluminum additions of 1.0, 2.2 and 6.7 percent were studied in one shipboard test. The unfavorable effects of these additions are shown in Figure 15.

Corrosion characteristics of anodes containing aluminum or cadmium, singly, also were inferior to those observed for the aluminum plus cadmium additions. The singular additions of aluminum or cadmium were, therefore, discarded as effective compositions.

Photographs showing the inferior corrosion characteristics of anodes containing singular additions of either aluminum or cadmium also are shown in Figures 9 and 10.

Small Test Anodes

Specimens used in small anode tests measured 2⅜ x 3⅞ x ½ inch and had an effective surface area of 22.2 square inches. Reduction in anode size from the 6 x 12 x 1¼ inch commercial anode caused unintentional alteration of anode current density and current output characteristics.

An initial anode current density of 2800 ma/sq ft was obtained with the small test anode used by Teel and Anderson. This value is approximately 3-8 times greater than observed in any work with commercial size zinc anodes. Typical differences in initial anode current densities obtained in quiescent exposure conditions are shown in Table 1.

Typical current output versus time curves of a 2⅜ x 3⅞ x ½ inch anode and a commercial size zinc anode are plotted in Figure 16. Note the nearly equal initial current output values obtained from these anodes. The current output of the small test anode fell 67 percent from its initial level during the thirty-one day test period. Current output obtained with the larger commercial size anode dropped less than 4 percent during the same time period.

These data emphasize the need for exclusive use of commercial size zinc anodes when compositional effects are being studied, and explain in part why conclusions from small test anodes were not confirmed in practice.

Barrier Shields

A ¼ inch thick barrier sheld of "Blown Asphalt" (200F MP, 10-13 penetration at 77F) was applied to the faying surface of anodes installed on the Navy YO Class Tanker. No asphalt or other barrier shield was applied to the faying surfaces of anodes in the other four commercial ship installations. No local attrition of the faying surface occurred in the absence of the barrier shield on zinc anodes.

These observations establish that barrier shields are not needed on the faying surfaces of zinc anodes installed on steel ship hulls.

Acknowledgment

Active ship tests involved installations on several operating vessels. The writers express special thanks to the owning and operating companies and their personnel, for the generous and excellent cooperation that made these tests possible.

References

1. R. B. Teel and D. B. Anderson. The Effect of Iron in Galvanic Zinc Anodes in Sea Water. *Corrosion,* **12,** 343-349 (1956) July.
2. Anodes, Corrosion Preventive Zinc: Plate, Slab, Disc and Rod-Shaped. MIL-A-18001A (Ships).

Any discussions of this article not published above will appear in the December, 1957 issue.

A Technical Note

Atmosphere Affects the Stress-Corrosion Failure of High Brass★

*By C. H. HANNON**

Abstract

Observed failures of high brass parts after prolonged service as arcing gap electrodes in electrical apparatus led to a special laboratory investigation. Failure of the electrodes was evidenced by disintegration, embrittlement, cracking and obvious oxidation. This article reports the observations made covering the effects of ammonia, oxygen, nitrous oxide and ozone on highly stressed brass test pieces. **6.3.6**

Introduction

OBSERVED FAILURES of high-brass parts after prolonged service as arcing-gap electrodes in electrical apparatus, led to the investigation described in this paper. Failure of the electrodes was evidenced by disintegration, embrittlement, cracking, and obvious oxidation. This article reports the observations made covering the effects of ammonia, oxygen, nitrous oxide and ozone on highly stressed brass test pieces.

Three types of specimens were used in an attempt to evaluate the effects of various atmospheres. Straight tensile-test pieces (Figure 1), "C"-shaped specimens preformed and subsequently additionally stressed (Figure 2), and special "V" shaped pieces (Figure 3), were employed. The exact conditions of exposure and the results obtained are reported in subsequent paragraphs.

Hard temper 70-30 yellow brass strip .025 x 7/8 inch was used in all the tests. At the outset of the investigation, tensile strip specimens were tested for tensile strength and percent elongation. Tests were made again after successive exposure periods of one month, six months and one year in a moisture saturated ozone atmosphere. In this and all other corresponding atmospheres, the ozone was generated with a General Electric Company 4 watt ozone lamp and the receptacle holding the specimens had a volume of approximately 425 cubic inches. During the exposure period a chocolate-brown adherent film formed rapidly. The film was identified by X-ray diffraction to be chiefly cuprous oxide, with some cupric and zinc oxide. There were indications in the photogram that the zinc oxide portion existed in the hydrated condition. From the data in Table 1, no embrittlement is evidenced and no change in tensile strength or elongation beyond experimental error is shown.

"C"-Shaped Test Pieces

All "C"-shaped test pieces illustrated by Figure 2 were made from strip having a developed length of 3 inches. The specimens were all preformed with a permanent set into "C" shaped parts having a cord dimension of 2 inches across the ends. Baldwin type A5-1 strain gauges were cemented to the preformed pieces and by means of small Nichrome bolts extending through 1/8 inch diameter holes near the ends of the specimens, the "C" parts were additionally stressed to just below the yield strength of the brass. This value had previously been measured at a 0.2 percent offset level. The clamping stress was determined by use of a Baldwin SR4 strain indicator.

Stressed "C" test pieces suspended on glass hooks were exposed in a moist ozone atmosphere for 253 days without evidence of cracking. A characteristic, dark brown, very dense, adherent film formed during the early part of the exposure period.

In other tests no cracking developed in stressed "C" specimens during a period of 132 days in a moist nitrous-oxide atmosphere. A superficial film, straw yellow in color, formed on the test pieces exposed to nitrous oxide.

In the case of tests in nitrous oxide or ozone, where no evidence of cracking could be observed, there was no problem of establishing a time of initial failure. Such was not the case involving tests in an atmosphere of ammonia. When highly stressed "C" specimens were suspended in a closed container over a solution composed of 10 percent reagent ammonium hydroxide and 90 percent water, it was impossible to detect when the initial crack developed. A dark bluish-green coating formed rapidly on the specimens and ultimately positive failure could be observed. The formation of many small cracks in the most highly stressed section characterized the failures.

"V"-Shaped Test Pieces

The decision to use "V" shaped test pieces illustrated in Figure 3 was made because of inability to determine the point of initial cracking. Data from empirical tests would at least be enlightening even though not absolute. The developed length of the test pieces was 4 7/8 inches and each piece was formed with two 1 3/8-inch long flat sides. This configuration permitted the test piece to be placed on one side with a load placed on the opposite side at location "A" (see Figure 3). Lead blocks, each weighing 600 grams, were employed to apply a constant load. By this procedure, the propagation of initial stress-corrosion cracks was caused to proceed rapidly and

★ Submitted for publication November 12, 1956.

* Transformer Laboratories Department, General Electric Company, Schenectady, New York.

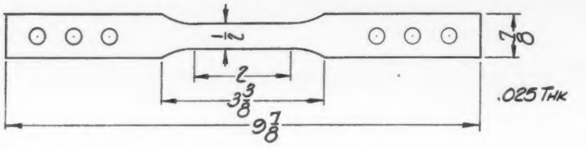


Figure 1—Straight tensile-test pieces.

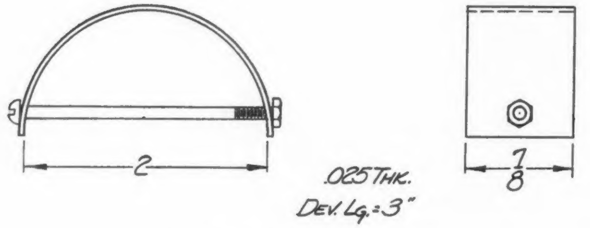


Figure 2—"C"-shaped specimens.

complete failures were consistently duplicated as indicated by the collapse of the specimen.

Under the constant-load conditions described, "V" specimens consistently failed within 24 hours when exposed in a closed container to the vapor over a 10 percent by volume ammonium hydroxide solution. In another test, the atmosphere over the ammonium hydroxide was thoroughly flushed with nitrous oxide to develop a combination of ammonia vapor and nitrous oxide. Loaded "V" specimens also broke within 24 hours in this atmosphere and the same failure life was obtained when oxygen was used to flush the atmosphere over a 10 percent ammonium hydroxide solution.

A most unexpected result was obtained in a combined atmosphere of ammonia and ozone. In one test, "V" specimens loaded in the manner previously described did not fail in 168 hours of continuous exposure. A check test under the same conditions did not show failure in 240 hours. Following the 240 hour period, the ozone source was shut off and the specimens failed within 24 hours.

While pronounced oxidation did occur in the presence of ozone, no embrittlement developed characteristic of the arc gap electrodes to which reference was previously made. It is, of course, possible that an atmosphere containing ozone was not continu-

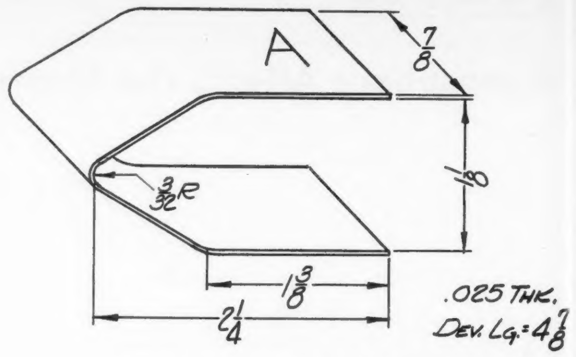


Figure 3—Special "V"-shaped test pieces.

TABLE 1—Tensile Specimens Exposed in Moist Ozone Atmosphere

	Tensile Strength	Percent Elongation
Specimens before exposure:		
(a)...............	78,400	6
(b)...............	80,000	6
Specimens exposed 1 month:		
(a)...............	78,000	6
(b)...............	79,500	6
Specimens exposed 6 months:		
(a)...............	79,600	5
(b)...............	79,200	5
Specimens exposed 1 year:		
(a)...............	78,800	6
(b)...............	78,400	6

ously maintained in the apparatus using the high-brass gap electrodes. It may have been that a reversing influence was prevalent, first of embrittlement due to ammonia followed by an oxidation reaction due to the generation of ozone by the gap discharges. The author has no new evidence indicating that stress-corrosion of the high brasses may be brought about in atmospheres other than those containing ammonia or possibly compounds of ammonia. The immunizing influence of ozone in the presence of ammonia is believed to be new knowledge and may possibly be explained by the formation and persistence of a film non-reactive with ammonia and consequently offering protection to the base metal. The stability and resistance of the film appears to be maintained only as long as ozone is present.

Any discussions of this article not published above will appear in the December, 1957 issue.

Discussions

Effects of Metal Cations on the Corrosion of Iron in Acids by Harry C. Gatos. *Corrosion,* Vol. 12, No. 7, 322t-330t (1956) July.

Question by Norman D. Groves, Richland, Washington:

The deleterious effects of metallic ions on the corrosion of ferrous alloys exposed to oxidizing acids has been investigated by this writer and other authors. Have you conducted any similar experiments?

Reply by Harry C. Gatos:

We have conducted no experiments in oxidizing acids containing metal cations. A systematic study of this nature should be of considerable interest.

Corrosion Control Practices for Pipe-Type Cables on the Detroit Edison System by W. A. Sinclair. *Corrosion,* Vol. 12, No. 8, 385t-388t (1956) August.

Question by W. S. Woodward, New York Telephone Company, New York, N. Y.:

Has cathodic protection been applied to the pipes described in your paper?

Reply by W. A. Sinclair:

Except for one river crossing we have not found it necessary to utilize cathodic protection on the pipes described in the paper. Most of our lines pass through highly congested areas which would provide us with a number of interference problems if cathodic protection were applied.

Application of the Statistical Theory of Extreme Values to the Analysis of Maximum Pit Depth Data for Aluminum by P. M. Aziz. *Corrosion,* Vol. 12, No. 10, 495t-506t (1956) October.

Question by E. H. Phelps, Applied Research Laboratory, U. S. Steel Corporation, Monroeville, Pa.

If you wanted to apply this method to another metal, would you merely measure the maximum pit depths on a series of specimens, plot the results on the extreme value probability paper, and see if a straight line is obtained?

What is your experimental method of determining the maximum pit depth on a specimen?

Reply by P. M. Aziz:

The method as outlined in the paper can be applied directly to the analysis of maximum pit depth data on other metals. The maximum pit depths obtained on a series of replicate samples would be ordered, ranked and plotted on extreme value paper. The linearity of the resulting plot would determine whether the data followed the extreme value distribution.

In order to determine the maximum pit depth on a specimen, it is cleaned of all corrosion product, and examined at low magnification (7x) under a binocular microscope. The deepest pit on each side of the specimen is selected and circled. In the case of aluminum this generally does not present any problems since there is usually one pit which is obviously deeper than all the others. If there is any doubt the four or five deepest pits are circled. The depths of the circled pits are then measured with a binocular bench microscope equipped with a vernier focussing screw calibrated in microns. The microscope is focussed on the pit shoulder and then on the base of the pit and the pit depth obtained from the vernier readings. The maximum pit depth for each specimen is then selected from these readings.

Stress Corrosion Cracking of Monel in Hydrofluoric Acid by H. R. Copson and C. F. Cheng. *Corrosion,* Vol. 12, No. 12, 647t-653t (1956) December.

Question by H. Howard Bennett, Socony Mobil Oil Co., Inc., Paulsboro, New Jersey:

Is there a threshold of oxygen concentration required for stress corrosion cracking of Monel?

Question by Ludwig Stern, Allied Chemical and Dye Corp., Camden, New Jersey:

Is anything known on the limits of moisture necessary to give stress corrosion cracking?

Reply by H. R. Copson to questions asked by H. Howard Bennett and Ludwig Stern:

The paper pointed out that cracking is most likely to occur where corrosion rates are high and that exposure to moist, aerated hydrofluoric acid vapor is the most dangerous condition. It is not possible, however, to put limits or threshold values on the permissible amounts of aeration or of moisture in the vapor. The limits would be expected to vary widely with conditions, and to be influenced by the temperature, by the amount of condensation, by flow rates, by the conditions of stress both internal and external, by the hardness of the material, by the duration of the exposure, and by other factors. Means of avoiding the cracking were discussed in the paper.

The Effect of Heat Treatment on the Susceptibility of Sand Cast Aluminum Alloy 220 to Stress Corrosion Cracking (Topic of the

Month) by Fred M. Reinhart. *Corrosion*, Vol. 13, No. 1, 1t-2t (1957) January.

Comments by A. M. Montgomery and H. C. Rutemiller, Alcoa Research Laboratories, Cleveland, Ohio: Sand cast aluminum alloy 220-T4 will provide outstanding mechanical properties when suitable casting and heat treating techniques are employed. It is essential also to properly quench the castings after solution heat treatment in order to attain satisfactory resistance to stress-corrosion cracking.

Mr. Reinhart's article on stress-corrosion cracking of alloy 220 presented conclusions that neglected one important factor. This was that one of the castings had aged at room temperature for a substantial period, whereas the others were tested very soon after reheat treatment.

Considerable effort has been devoted by Alcoa to the selection of preferred quenching practices in the development of 220-T4 alloy. It was determined that freshly quenched 220-T4 has a high resistance to stress-corrosion cracking, regardless of the quenching rate. However, the alloy ages at room temperature, particularly when rapidly quenched, so its resistance to stress-corrosion cracking may be impaired. This lowered resistance may require an aging period of six months or longer to become evident. If sufficient time has elapsed, it will be found that the susceptibility to stress-corrosion cracking increases directly with the severity of quench.

A slow quench has been used by Alcoa for many years in producing alloy 220-T4 castings to impart adequate resistance to stress-corrosion cracking. The optimum quenching rate is obtained with an oil quench at 250-300 F or an interrupted boiling water quench of 10-30 seconds duration followed by an air cool. These quenching practices were patented by Alcoa and have been recommended to licensees. The same information was supplied in the "Foundry Manual for Sand Casting Aluminum—10 PerCent Magnesium Alloy", prepared for the Frankford Arsenal by Battelle Memorial Institute on July 31, 1954.

A "sensitizing" treatment of 30 hours at 212 F has the same effect as a few years of natural aging on the susceptibility to stress-corrosion cracking of 220-T4 alloy. This treatment does not affect the tensile properties but permits determination of resistance to stress-crossion cracking without delay. If this sensitizing treatment had been used in the tests described by Mr. Reinhart, or if sufficient room temperature aging had ensued prior to testing, the reheat treated specimens quenched in boiling or cold water would have cracked in a very short time.

On the other hand test bars removed from castings properly quenched in hot oil or with the interrupted boiling water quench and sensitized or aged for an extended period at room temperature show excellent resistance to cracking under accelerated test conditions

Stress-corrosion cracking generally is not encountered in properly quenched alloy 220-T4 castings subjected to normal design stresses.

Reply by Fred M. Reinhart:

The comments of Mr. Montgomery and Mr. Rutemiller are much appreciated.

With regard to the statement that the conclusions neglected to point out that one of the castings had aged at room temperature for a substantial period whereas the others were tested very soon after reheat treatment, the article stated that specimens were tested in the "as received" condition which would, in this case, mean that the specimens were machined from castings which had failed in use and which had been in storage for some period of time.

Subsequent work has shown that specimens solution heat treated at 810 F for 18 hours which were quenched in hot oil at 300 F for about 10 minutes, cooled to room temperature in tap water and artificially aged at 212 F for 30 hours failed by stress corrosion cracking within two hours when stressed at 75 percent of the yield strength (18,000 psi) and intermittently immersed in the $NaCl-H_2O_2$ solution. Specimens heat treated and quenched in the same manner but aged at room temperature for 96 hours failed, when stressed and tested under the same conditions in from 445 to 730 hours (18 to 30 days). These tests indicate that the hot oil quench and sensitizing or room temperature aging of the material in question did not render it immune to stress corrosion cracking.

The magnesium content of this alloy is important from the standpoint of stress corrosion resistance. When the magnesium is on the high side of the compositional range, the alloy overages during exposure to slightly elevated temperatures; in this condition, its tensile properties deteriorate and the alloy may become susceptible to stress corrosion.[1] Chemical and spectrochemical determinations showed that the magnesium content in the thin sections averaged 10.45 percent and 11.05 percent in the thick sections. With magnesium contents at the top and above the compositional range it is not surprising that the resistance of this material to stress corrosion cracking is low at room temperature.

It appears that in order to render this alloy resistant to stress corrosion cracking in sea atmosphere environments, not only must the heat treatment be closely controlled and the residual and applied stresses accurately determined but the magnesium content must be kept on the low side of the compositional range. If this is not done, the alloy will be susceptible to stress corrosion cracking and fail in service similar to those castings reported in the article.

Reference

1. Development of Sand-Cast Aluminum Base Alloys Having Improved Properties. PB 111699, Office of Technical Services, United States Department of Commerce.

Effect of Hot Hydrogen Sulfide Environments On Various Metals. Publication 57-2. *Corrosion*, Vol. 13, No. 1, 27t-36t (1957) January.

Comment by Norman S. Bawta, Beaumont, Texas:

Please make a rough sketch showing the design of the "Radial Flow" in reactor.

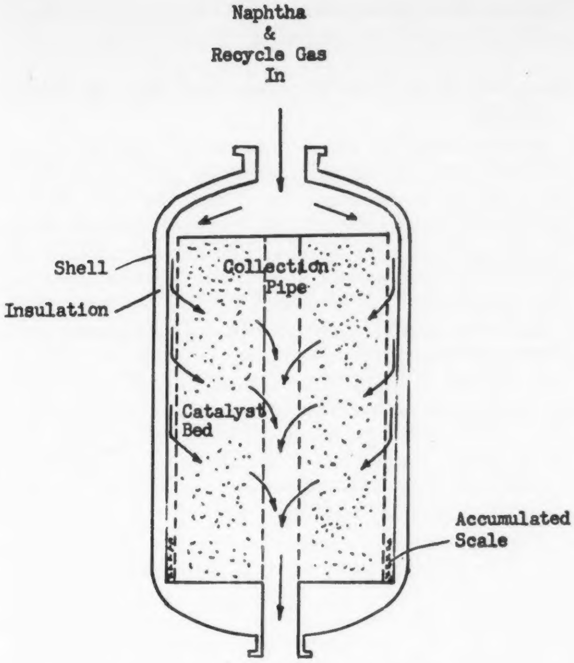


Figure 1—Sketch of radial flow reactor.

Reply by Frank J. Bruns:

Thank you for your interest in our paper. In response to your request we are attaching a schematic drawing (Figure 1) showing this arrangement. Naphtha and recycle gas flow downward then pass radially through the catalyst bed from an annular space between the bed and reactor walls. Iron sulfide scale which enters the reactor with the stream drops out in the annulus, from which it is removed during shutdowns.

High Temperature Sulfide Corrosion in Catalytic Reforming of Light Naphthas. Publication 57-3. *Corrosion*, Vol. 13, No. 1, 37t-42t (1957) January.

Comment by E. B. Backensto, Socony Mobil Oil Co., Inc., Paulsboro, New Jersey:

The data presented in Publication 57-3 show that the corrosion rate for 12 percent chromium steel is about the same as the corrosion rate for the 0-9 percent chromium steels at 900 to 1100 F over a wide range of H_2S concentrations. As a matter of fact, Table 2 shows that in 9 out of 13 tests the corrosion rate for the 12 percent chromium steel was slightly higher than the rate for the 9 percent chromium steel tested. While these data are contrary to our findings (*Corrosion*, 12, No. 1, 6t-16t (1956) January) we did point out that the corrosion resistance of the 7-16 percent steels was unpredictable.

Some unknown property of 12 percent chromium steel may have caused this anomaly. We have noted in several of our tests that the corrosion rates of Type 410 steel from one source appear to be higher than rates for the same type of steel from another supplier. These are both wrought steels and, as far as can be determined, neither had undergone any unusual treatment prior to testing.

To illustrate this observation, we can use the test results for the Beaumont and Torrance TCR units which we summarized earlier (*Corrosion*, **12**, No. 5, 235t-244t (1956) May). Table 1 of our paper shows that there is no significant difference in chemical analysis of the two Type 410 steels tested, identified by (d) and (e) in the table. At the ten test locations in the Beaumont unit, all of the (e) specimens gave higher corrosion rates than the (d) specimens. The corrosion rates for Type 410(e) averaged nearly seven times (range: 1.2 to 19) the rate for Type 410(d); most of the corrosion rates were between 0.001 and 0.007 in/yr. This same pattern did not occur for the test run in the Torrance unit. On comparing results for the (d) and (e) specimens, at two Torrance test locations the corrosion rates were the same, at four locations (e) was 5 to 30 percent lower than (d), and at the four remaining locations (e) was 20 to 80 percent higher than (d). In this test the corrosion rates were generally between 0.01 and 0.07 in/yr.

During the discussion Dr. Birchenall suggested that the steels be checked for oxygen inclusions since such inclusions act as a barrier for H_2S corrosion. We have done this and found no significant difference in the number or type of inclusions.

John Halbig of Armco Steel suggested that we check the chromium/carbon ratio which has proven quite critical in other corrosion work, and the type of steel, whether ferritic or martensitic. The chemical analyses given in Table 1, referred to above, show very little difference in the chromium/carbon ratio for the (d) and (e) specimens. There is no doubt that both these materials were martensitic. In this regard we have observed that Type 410 steels generally exhibit higher corrosion rates than Type 405 steels under high temperature hydrogen-hydrogen sulfide corrosive conditions.

Electrical Resistance Corrosion Measurements Employing Alternating Current by W. L. Denman. *Corrosion*, Vol. 13, No. 1, 43t-50t (1957) January.

Comment by G. A. Marsh and E. Schaschl, The Pure Oil Co., Crystal Lake, Illinois:

Dr. Denman states that we "passed a known direct current through the corrosion specimen and measured the voltage drop. The electrical resistance of the corrosion specimen was then calculated from the values of voltage drop and current using Ohm's law."

The facts are that we have always used alternating current in our corrosion meter. No calculation of resistance is made, as our instrument is calibrated directly in metal penetration units.

Lead Cable Sheath Corrosion Under Cathodic Protection Conditions by Walter H. Bruckner and Ray M. Wainwright. *Corrosion*, Vol. 13, No. 2, 143t-148t (1957) February.

Comment by Oliver Henderson, The Ohio Bell Telephone Company, Cleveland, Ohio:

The conclusion reached in this paper, that corrosion of lead cable due to de-icing salt occurs during those periods when there is no protective current seems to be borne out in our experiences in Cleveland.

After the discontinuance of the electric street cars, the need for heavy salting of track switches disappeared. Also the application of black top to the streets effectively reduced the chances for the de-icing salt to filter down into the conduit runs.

These changes in the situation made it opportune to flush out the already deposited chloride products at this time. However, the success in duct flushing has been only partial because deposits are encountered at times that are so insoluble and hard as to be impossible to dislodge with plain water.

I believe that the author of the paper could enhance his contribution to the art by determining what additives to the water would effectively bring about a thorough cleaning out of the already contaminated ducts containing lead cables.

Reply By Walter H. Bruckner and Ray M. Wainwright:

In reply to Mr. Henderson, we will say that we are pleased to have his confirmation from field experience of the extreme crust formation which we have observed on cathodically protected specimens in this laboratory. We are also pleased to have his comments regarding the incidence of cable corrosion in relation to the supply of protective current. This seems to be the experience in general (i.e., where a cable is continually submerged there is a low incidence of corrosion and where loss of protection can occur due to water level change, deterioration can be quite rapid.) We have recently found that complete loss of cathodic protection is not necessary for rapid deterioration, since a partially submerged but cathodically protected cable may encounter the most hazardous corrosion environment at or slightly above the water line.

We are interested in what Mr. Henderson says in relation to the removal of crusts from cathodically protected cable in ducts. We have been thinking along these lines and have carried out some tests to determine the effectiveness of NH_4Cl additions to the de-icing salt to *prevent* crust formation. Such addition can be made so effective that crust formation is entirely absent. We have not yet had the opportunity to determine the effectiveness of the addition on crust removal. We would note, however, that the use of NH_4Cl may, in a highly alkaline environment, produce volatile NH_3 and provide an extreme hazard in deterioration of any exposed copper.

Questions by Howard A. Hoover, John A. Roebling's Sons Corp., Trenton, New Jersey:

Could you determine whether or not the corrosion at the cathode area was intergranular?

To what extent would the composition of the lead itself affect the corrosion?

Would the presence or absence of anodic or cathodic grain boundary phases in lead alloys have any effect on the type and amount of "cathodic" corrosion under the conditions described in the paper?

Reply by Walter H. Bruckner and Ray M. Wainwright:

In answering Mr. Hoover we can say that the corrosion was general and did not involve grain boundaries specially. It is our experience that the corrosion of lead cable sheath occurs due to the cessation of cathodic protection in an environment of variable pH depending upon extent of previous cathodic protection. Any condition such as a second phase at grain boundaries would increase the corrosion rate in a highly alkaline electrolyte. Any alloy content of the lead should preferably be low in amount and be in solid solution rather than precipitated or a separate phase. We have at the University concerned ourselves with commercial lead sheath alloys which on occasion have contained antimony, arsenic, copper, either singly or in combination.

We would like to emphasize that we have not presented a study of cathodic corrosion since the latter occurs at extremely high current densities which are, we believe, out of the realm of consideration as a reason for the service failures which have been observed. A description of the service failure of lead cable sheath is a general roughening of the surface and coloration ranging from yellow to pink or red. Pinholing may occur in portions of the rough, corroded surface. The examples of laboratory sheath corrosion under alkaline environment upon cessation of cathodic protection are similar to the service failures.

Comments by Morris B. Hart, Illinois Bell Telephone Co., Chicago, Illinois:

The conclusions reached by the authors do not appear to correspond to our experiences in actual field work. In corrosion mitigation work on underground telephone cables in Chicago during the past fifteen years we have had an average of perhaps twenty cable failures per year which we think have been due to cathodic corrosion (i.e., to corrosion which occurred while the cables were continuously negative to earth.) In all of these cases we believe that the corrosion resulted from a combination of negative sheath in the presence of de-icing salt (NaCl).

We have at present a controlled field experiment underway in Chicago in which the preliminary inspection (at the end of 4½ months) appears to support this belief. A copy of our report on this experiment is reproduced below:[1]

The increasing need for cathodic protection systems to control cable sheath corrosion is becoming more apparent daily. The value of this method of corrosion prevention has been proven conclusively, but there has always been some question as to the possibility of such a system actually causing corrosion under certain conditions. In order to secure some information as to the possibility of this occurring, the following experimental installation has been made.

Four pieces of 606 pair 24 gauge cable were obtained. Each of these was about 5 feet long, 2½ inches in diameter, and with a lead sheath clean and smooth. The ends were sealed with solder, and a No. 12 insulated wire was soldered to one end of

[1] Report bears the title: "Cathodic Corrosion of Lead Sheathed Cables—A Field Experiment in Chicago." Author of report is M. B. Hart.

each of the samples. This joint was not covered or insulated. Two trenches were dug about two feet deep and one foot wide near the base of a pole at 91st Street and east of Halsted Street. Two of the prepared samples were placed about six inches apart in each trench, and one sample of each pair of cables was connected to the negative post of a nearby rectifier. The lead wire of the other sample in each pair was left dead lying along-side the sheath. The trenches were then backfilled, one with earth mixed with cinders and the other with earth mixed with rock salt. The positive side of the rectifier was connected to a ground bed consisting of three graphite and three Duriron anodes, the closest one being about 125 feet from the above pole. The rectifier was set at about 11 volts.

This installation was made Sept. 28, 1955 and the following day it was found that the cable in the salt environment was picking up about 100 milliamperes (about 20 milliamperes per square foot) and the one in the cinder environment was taking about 1/10 of this amount of current. Frequent tests were made to check this current flow, and although there was some fluctuation, the current remained fairly constant. However, on Feb. 9, 1956 it was found that the current had dropped down to about one-half of the above values and since there had been a recent conduit installation near this pole, it was feared that the lead wires might have been damaged. It was decided to dig up and check this, and it seemed an opportune time to inspect the samples. The electrolysis engineers of the Commonwealth Edison Company were notified, and Mr. Perry and Mr. Rose of that company were present when the digup was made on the afternoon of Feb. 9.

When the sample cables were exposed, it was found that the lead wires were intact, and that the decrease in current was probably due to frozen earth, the frost being about one foot deep. Examination of the sheaths disclosed the following:

1. In the salt free cinder environment:
   A. The free sheath (not connected to the rectifier) was slightly pitted on the side near the protected cable.
   B. The cathodically protected sheath was clean and showed no signs of corrosion.
2. In the salt environment:
   A. The free cable showed slight signs of corrosion on the side near the protected cable.
   B. The cathodically protected cable showed typical cathodic corrosion signs. A large portion of the sheath was covered with a brilliant red deposit (apparently an oxide of lead) which had not been on the sheath when it was buried, and which did not appear on any of the other samples. There was a deposit of white crystals (apparently salt) covering most of the sheath. The sheath was etched pretty well over its entire surface, with no deep pits. A litmus paper test of the moisture on the sheath and in the nearby earth showed strongly alkaline.

After the inspections were completed, all cables were returned to their original places and covered as before, with the addition of fresh rock salt to the backfill where salt was used previously. It is planned to continue the test, and to inspect the sheaths again in about six to eight months.

There can be little doubt but that these two samples were continuously cathodic (about 1 volt negative to nearby earth, using a lead reference electrode) for the 4½ months since their installation. As stated previously, frequent checks were made (once or twice a month) to see that the current was not interrupted. Since the lead wires were not disturbed and since the circuit breaker in the rectifier is not automatically resetting, there is no reason to believe that the current from the samples was ever interrupted. Therefore, any corrosion on these samples must have taken place while under cathodic protection. Based on this initial examination, but reserving final judgment pending later inspections of these samples, it appears that we may make the following statements:

1. Salt greatly decreases the earth resistivity, and increases the current flow to cables under cathodic protection.
2. Lead sheaths that are cathodic in salt will corrode.
3. Our present method of identifying cathodic corrosion is correct. It is based on corrosion product colors, litmus paper test, and lack of steep sided pits.
4. Unprotected cables near cathodically protected cables are likely to corrode.

It appears then, that cathodic protection systems should be used with caution in any area where de-icing salts may be present. Also, care should be taken to see that other underground structures are not damaged by these installations.

It is of interest to note that the number of cases of cathodic corrosion cases per year reached its peak before the beginning of the reduction of street car service in Chicago. Since the reduction of street car service and the consequent decrease of cathodic protection there has been a decided decrease in the number of cathodic corrosion cases.

Reply by Walter H. Bruckner and Ray M. Wainwright:

In answering Mr. Hart, we should note that we have had some contacts with him since the presentation of our paper. We have inspected his company's field test samples and found that there was indeed evidence of corrosion of cable under cathodic protection in salted earth. However, when the level of protection was related to the actual sheath surface pH and the Pourbaix diagram for potential and pH of lead, it was found that corrosion could have been anticipated. We hope soon to have a paper for presentation to the NACE, in which we will present the results of studies made on lead and which confirm the value of the Pourbaix diagram in controlling the effective use of cathodic protection on lead cable sheaths. We hope also to present data obtained in field-simulated tests and will then have a further answer for the discussion which Mr. Hart has made. We would like to commend Mr. Hart for his initiative in undertaking the field tests, and we share his hope for results of maximum acceptance.

Polyvinylidene Chloride Film and Microcrystalline Wax for Protecting Underground Pipe by Ted Kennedy, Jr. *Corrosion,* Vol. 13, No. 3, 186t-190t (1957) March.

Question by Lawrence O. McCormick, Baltimore Gas and Electric Company, Baltimore, Maryland:
What is the maximum pipe operating temperature on which combined polyvinylidene chloride film and microcrystalline wax can be used successfully?

Reply by Ted Kennedy, Jr.

Microcrystalline wax and polyvinylidene chloride film have been successfully used for over four years on a 24-inch line at 110-120 F. Other wrapper specifications are recommended for use with microcrystalline wax at temperatures above 150 F.

The wax above 120 F or so is in a continued soft state. However, this appears to be no disadvantage since soil will not "grab" into the plastic film nor can it totally displace the wax from under the film. Actually, a rather impressive argument can be made in behalf of a "soft" coating providing it can be protected from soil stress and displacement.

Question by Daniel R. Werner, American Telephone and Telegraph Company, Kansas City, Missouri:
Does the wax applied alone have any abrasion resistance qualities?

Reply by Ted Kennedy, Jr.:

Microcrystalline wax should *not* be used without a properly designed protective wrapper under any conditions where the coating itself will be in physical

contact with any elements of the surrounding environment. This is perhaps not a direct answer to the question asked but since abrasion cannot occur without some actual physical contact with the wax itself and since it is understood that under abrasive conditions a wrapper is always recommended the question no longer is in point.

Question by W. A. Sinclair, Detroit Edison Company, Detroit, Michigan:

What voltage is used for holiday testing of your coating?

Reply by Ted Kennedy, Jr.:

The microcrystalline wax wrapped with polyvinylidene chloride and overwrapped with 80-pound Kraft paper is "jeeped" at 6,000 volts.

Question by Elmer Westerhof, Consumers Power Company, Jackson, Michigan:

What current is required in ma/ft^2 on your coating when first installed for protection and does this increase with time? How do various soil and water conditions affect the current required for protection?

Will the polyvinylidene chloride film suffer deterioration if wax is applied at excessively high temperatures, say 350 to 400 F?

Replies by Ted Kennedy, Jr.:

It has been the experience of the Trenton Corporation that a year or more is required for the soil adjacent at a pipeline to stabilize. The length of time required for this stabilization depends upon the weather during the interim and the type of soil in which the line is layed. Since current requirements vary with the degree of the stabilization of the backfill it is very difficult to say what the initial ma/ft^2 might be expected to be. However, once the soil is stabilized and the initial current requirements determined, these current requirements will remain relatively constant. Variations in soil or water conditions appear to have little effect on the current required.

Field tests indicate that 1 or 2 amps of current will protect 40-50 miles of 8-inch pipe in 2,000-10,000 ohm soil with the average number of shorted casings. Of course this is a most general figure.

The polyvinylidene chloride film has been successfully used at temperatures near 130 F. The melting point of the plastic is 300 F. Other wax coating and wrapper specifications are recommended for temperatures above 150 F.

Questions by E. G. Brink, American Viscose Corporation, Marcus Hook, Pennsylvania:

1. What plastic films were evaluated in comparison with polyvinylidene chloride before deciding to use the polyvinylidene chloride?
2. Is it uneconomical to use a heavier plastic film in order to obtain greater protection from mechanical damage?
3. Is the pipe preheated before applying the wax at sub-freezing temperatures? How are defects in the film repaired?

Replies by Ted Kennedy, Jr.:

1. All films commercially available at the time of original design of the microcrystalline wax-polyvinylidene chloride film system were evaluated. The soundness of the original selection of polyvinylidene film as the wrapper component of this specification is proven by the fact that though continuing research on both old and new plastic film is being carried on, there is none yet considered to be equal to the plastic film (polyvinylidene) originally selected.
2. Field experience indicates that though a thicker film would be stronger, it is not necessary. The toughness of the present film thickness used is adequate to properly function under all conditions where additional protection is not required for other coatings and wrappers.

   Where ditch padding and special handling are required for old-type coatings and wrappers, the same should be provided with the microcrystalline wax-polyvinylidene chloride film specifications.

   To date it does not appear economically feasible to meet the rigors of ditch conditions that require special handling by increasing film thickness.
3. Pipe need not be preheated in sub-freezing weather as long as the pipe surface is dry. If the pipe surface is dry, application can proceed during any low temperatures in which it is still feasible to carry on pipe line operations. These materials have been successfully applied at temperatures as low as 10 degrees below zero.

Corrosion Measurements in a Hydrogen Sulfide-Water Absorption Pilot Plant by B. W. Bradley and N. R. Dunne. *Corrosion*, Vol. 13, No. 4, 238t-242t (1957) April.

Question by J. A. Rowe, Jr., Houston, Texas:

In Table 3 how do you account for the fact that 5 percent Ni did not fail?

Reply by B. W. Bradley:

In the paper, it was stated that each sulfide corrosion cracking specimen was stressed to a nominal outer wall fiber stress of 120,000 psi. This, of course, is only theoretical since all specimens were not completely elastic up to that stress. Therefore, it is more exact to say the specimens were stressed to an equal deflection rather than an equal stress. If one specimen has a lower yield strength than another, then its stress at a given deflection is less. We feel the 5 percent Ni specimen fell in this category since it is known to have a lower yield strength and is a softer material than others surrounding it in Table 3. We believe this is the reason that it did not fail in the field test.

TECHNICAL COMMITTEE ACTIVITIES

Refining Industry Committee Functions Outlined

32 Committees Schedule Meetings at Four NACE Regional Sessions This Fall

Thirty-two committees plan meetings during NACE regional meetings to be held this fall. Technical committees have been invited to hold meetings at the Northeast Region meeting in Pittsburgh, November 12-14; the North Central Region in Chicago, October 1-4; South Central Region in Oklahoma City, October 1-4; and the Western Region at San Diego, October 23-25.

Meetings tentatively scheduled:

North Central Region

T-7B, North Central Region Corrosion Coordinating Committee

Northeast Region

T-2E, Internal Corrosion of Product Pipe Lines and Tanks
T-2K, Prefabricated Plastic Film for Pipe Line Coating
T-3C, Annual Losses Due to Corrosion
T-3E-1, Corrosion of Railroad Tank Cars
T-3H, Tanker Corrosion
T-5D, Plastic Materials of Construction
T-5A-6, HF Corrosion
T-6F, Protective Coatings Equipment, Methods and Costs
T-7A, Northeast Region Corrosion Coordinating Committee

South Central Region

T-1, Corrosion in Oil and Gas Well Equipment
T-1B, Condensate Well Corrosion
T-1D, Sour Oil Well Corrosion
T-1F, Metallurgy
T-1F-1, Sulfide Stress Corrosion Cracking
T-1H, Oil String Casing Corrosion
T-1K, Inhibitors for Oil and Gas Wells
T-2C, Minimum Current Requirements
T-2D, Standardization of Procedures for Measuring Pipe Coating Leakage Conductance
T-2F, Internal Corrosion of Crude Oil Pipe Lines and Tanks
T-2G, Coal Tar Coatings for Underground Use
T-2J, Wrappers for Underground Pipe Line Coatings
T-2K, Prefabricated Plastic Film for Pipe Line Coating
T-3G, Cathodic Protection
T-5C-1, Corrosion by Cooling Water
T-5E, Stress Corrosion Cracking of Austenitic Stainless Steel
T-6A, Organic Coatings and Linings for Resistance to Chemical Corrosion
T-6B, Protective Coatings for Resistance to Atmospheric Corrosion
T-6D, Industrial Maintenance Painting
T-6E, Protective Coatings in Petroleum Production
T-7D, South Central Region Corrosion Coordinating Committee
T-8, Refining Industry Corrosion

Groves and Meyer Elected By Nitric Acid Group

N. D. Groves, Carpenter Steel Company, Reading, Pennsylvania is the newly elected chairman of Task Group T-5A-5 on Corrosion by Nitric Acid. F. H. Meyer, Jr., National Lead Company, Metallurgical Department, Cincinnati, Ohio was elected vice-chairman.

J. L. English, Oak Ridge National Laboratory, Oak Ridge, Tennessee is the retiring chairman and W. H. Burton, General Chemical Director, Allied Chemical & Dye Corporation, Camden, New Jersey is the retiring vice-chairman. During their term in office three reports on corrosion by nitric acid were completed by the committee.

Hoy is North Central Chairman of T-7B


Hoy

Paul C. Hoy, Corrosion Control Engineer of the Gas Department of the Dayton Power & Light Company, Dayton, Ohio has been appointed chairman of the North Central Region Corrosion Coordinating Committee. Mr. Hoy has been engaged in pipeline corrosion control work for the past 10 years. He has been chief corrosion engineer for the New York State Natural Gas Corporation in Pittsburgh, Pa. and was at one time associated with the Peoples Natural Gas Company of Pittsburgh. He is a past member of the Western Pennsylvania Corrosion Committee.

J. O. Manly of the Michigan Consolidated Gas Company in Detroit is vice-chairman of Unit Committee T-7B North Central Region of Corrosion Coordinating Committee.

Domestic Hot Water Tank Group Formed by T-4E

A task group on hot water tank corrosion has been formed recently by Unit Committee T-4E on Corrosion by Domestic Waters.

The task group has been designated T-4E-1. T. E. Larson of the Illinois State Water Survey in Urbana, chairman of T-4E said R. C. Weast of Case Institute of Technology in Cleveland, Ohio has been appointed chairman of the group.

Profitable Subjects For Investigation Weighed by Group

Members of newly organized Technical Group Committee T-8 on Refining Industry Corrosion discussed subjects for possible committee investigation at a meeting March 14 in St. Louis as follows:

1. The formation, purposes and activities of inter-refinery and/or inter-company corrosion committees.

2. Corrosion associated with and the economic mitigation of corrosion in tubular coolers and condensers in recirculated water systems.


Backensto


Holmberg


Phillips

3. Stress corrosion cracking of quenched and tempered steel, i.e. high strength bolting materials such as ASTM B-193, Grade B-7. Failure usually is associated with hydrogen absorption as the result of corrosion by contaminated waters present in exchangers, coolers and condensers, and by other media, particularly acids used in certain refinery processes.

4. Use of, and control procedures for chemical cleaning methods in the modern refinery.

5. Naphthenic acid corrosion. Damaging corrosion has been attributed to it, even though actual corrosion was not similar to that described in literature.

6. Corrosion of exchangers and condensers by cooling waters, particularly the value of fighting this corrosion by means of cathodic protection, metallizing, Neoprene and other linings and their comparative effectiveness.

7. The use of duplex exchanger and condenser tubing in oil refining. Disconcerting failures have occurred due to hydrogen blistering and other causes. A survey of their effectiveness may be very beneficial.

(Continued on Page 84)

Refinery Industry—

(Continued From Page 83)

Exchanger, Condenser Problems

There is a need to study corrosion in exchangers and condensers. Information is needed on water composition and treating procedures, use of inhibitors and anodes and coatings. Also a uniform, rational manner of developing water control procedures is needed.

Some examples of the seriousness and nature of the problem were given. It was estimated approximately a quarter million dollars a year is required for bundle replacement at one refinery. Proper design was mentioned as an important factor in cooling water corrosion. The comment was offered that pitting due to concentration cell corrosion had been experienced under low velocity conditions in exchanger shells using well treated water.

Inhibitor films cannot be relied on when water velocities are less than 2 fps. Coatings used are not always successful. For many years, one refinery has had its cooling water problems under control, but this situation has changed as a result of the necessity for developing new sources of water.

The troublesome problem of stress corrosion cracking of high strength bolting material was discussed at length. Slides illustrating the stress corrosion cracking of ASTM B-193 Grade B-7 bolts in a fluid catalytic cracking unit light ends system were shown. The brittle failures were attributed to hydrogen absorption resulting from corrosion.

Bolt Tests Made

To study the problem, test blocks were made and ¾ inch bolts were stressed to different levels. The test was very similar to that described in the paper "Sulfide Corrosion Cracking of High Strength Bolting Material" by Donald Warren and G. W. Beckman, presented at the 1957 NACE Conference.*

A critical stress was found at approximately 80 percent of the yield point. On B-7 bolts having a yield point of 100,000 psi no cracks developed at 75,000 psi, but above 80,000 psi, the bolts invariably cracked.

It was found that pneumatic impact wrenches normally used in refineries, are powerful enough to stress bolts to above the yield point. Use of smaller wrenches or limiting air pressure was given as possible remedies for overstressing by pneumatic wrenches.

Other suggestions and experiences concerning this problem were brought out. One suggestion for alleviating susceptibility to failure was to use bolts tempered to high temperatures instead of using B-7 bolts. Use of large bolts of softer materials less susceptible to stress corrosion cracking also was suggested. Indications were that the length of the bolt is not a critical factor in the amount of stress developed when checking torque.

Hydrogen Embrittlement Scanned

One experience with low alloy steel springs was cited. Springs charged with hydrogen electrolytically in the laboratory broke at stress levels as low as 25,000 psi. This suggested that the degree of hydrogen absorption is a controlling factor. Other materials were examined and many alloys became embrittled by hydrogen. Exceptions were copper, tantalum and certain alloys.

Chemical cleaning, another principal source of corrosion trouble was discussed. In order to prevent corrosion and other damage to equipment, better control methods are needed for acid cleaning of refinery process equipment. Other suggestions were to establish close cooperation with contractors prior to construction considering the metals in the system, acid strength, washing practices, neutralization and a thorough understanding on the part of all concerned. The need for discussion of control procedures and follow-up by qualified technical personnel was also pointed out.

Some refineries have appointed one man whose responsibility is to follow cleaning operations. In one refinery, this takes three-fourths of one man's time. Some refineries do the job themselves instead of contracting it and save half to three-fourths the cost. In other areas, a contractor can do the job cheaper.

The consensus was that control of cleaning methods appeared to be indefinite. Chemical cleaning was recognized as a potential source of serious corrosion.

Design Problems Considered

The comprehensive problem of combatting corrosion through proper design was discussed at length. It was suggested that the collection and dissemination of design practices useful in con-

* The test was designed so that even bearing was obtained by using surface-ground washers and nuts. Torque on neighborng bolts was not affected by tightening individual bolts.

(Continued on Page 86)

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at $10 a column inch.

Positions Available

Wanted—Corrosion Engineer—Minimum requirements: BS degree, 5 years' experience in design of corrosion control systems for pipe lines, refineries, marine installations and water systems. Opportunity to head engineering section of large service organization. CORROSION, Box 57-7.

Unlimited Opportunity Available as representative of nationally advertised industrial marking Paintstiks. Sold to Industrial Distributors exclusively. Extensive national advertising campaign constantly furnishes sales leads to be contacted. In reply, please describe your territory and names of other manufacturers represented. Write CORROSION, Box 57-9.

Wanted—Large manufacturer of a complete line of heavy duty maintenance paints needs experienced corrosion engineer for laboratory and service work leading to sales if desired. All replies confidential. Write today. CORROSION, Box 57-10.

The Third Annual Titanium Lecture Program of New York University's College of Engineering will be held September 9-13. Attendance is limited. Applications and information are available from Harold Magolin, New York University, University Heights 53, New York City.

Positions Wanted

Corrosion Engineer: 12 years' experience corrosion control cooling and process systems. Research and technical service on control measure-inhibitors, water conditioning, testing (coupon, electrical), material evaluation, cathodic, design. Plant corrosion program planning. B.S. Ch.E., Graduate work. CORROSION, Box 57-8.

T-6F to Concentrate On Interior Linings

Unit Committee T-6F on Protective Coatings Equipment Methods and Costs recently requested that the title of the committee be changed to "Protective Interior Linings Application and Methods." The proposal is presently under consideration by Group Committee T-6 on Protective Coatings. T-6F members are primarily interested in interior linings and wish to confine their work and study to linings.

Cathcart

W. P. Cathcart of the Tank Lining Corp., Pittsburgh, Pennsylvania, Chairman of Unit Committee T-6F recently announced the formation of five T-6F task groups. The task groups and their chairmen are: T-6F-1 on Curing, K. G. Lefevre, Metalweld, Inc., Philadelphia, Pennsylvania; T-6F-2 on Surface Preparation, L. R. Mangram, Linco, Inc., Houston, Texas, chairman; T-6F-3 on Inspection, L. Barker, Carbide and Carbon Chemicals Corporation, South Charleston, West Virginia, chairman; T-6F-4, on Safety, chairman to be announced; T-6F-5 on Application, H. Foelsch, A. Gusmer, Inc., Woodridge, New Jersey, chairman.

A. R. Gabel of the Dow Chemical Company in Midland Michigan and J. H. Cogshall of the Pennsylvania Salt Manufacturing Company, Philadelphia, Pennsylvania were recently elected vice-chairman and secretary respectively of Unit Committee T-6F.

Next meeting of T-6F will be held in Pittsburgh during the 1957 North East Regional Meeting, November 12-14.

Vollmer is Vice-Chairman Of T-1F on Metallurgy

Leslie W. Vollmer of the Gulf Research and Development Company in Pittsburgh has been elected vice-chairman of Unit Committee T-1F on Metallurgy. Mr. Vollmer graduated from Penn State College in 1926 and has been engaged in corrosion mitigation work in the drilling, production, transportation and refining of petroleum since 1929. He has been a member of NACE since 1950 and has actively participated in T-1 activities since that time.

He was especially active in the activities of Unit Committee T-1G on Sulfide Stress Corrosion Cracking and was a member of that committee's steering group on the sulfide stress corrosion research project sponsored by T-1G at Yale University.

Refinery Industry—

(Continued From Page 84)

trolling corrosion would be a good field for T-8 activity. Preparation of a corrosion guide for design engineers would be very useful and a valuable tool, it was said. It was decided to give further consideration to the problem before committing the group to specific action.

Some of the points brought out during the discussion were:

1. Corrosion information to be used in design planning may not be interpreted properly. However, it was pointed out that the problem here usually was a lack of information rather than improperly used information. Data should be considered only as a guide and not as specifications, it was said.

2. It is difficult to prepare a guide that will take into account all possible factors. As a result, a guide would not necessarily eliminate all mistakes.

3. The most effective use of corrosion information is realized when corrosion is considered in the designing stages of equipment. For this reason, it is desirable to furnish designers with suitable corrosion information.

Next T-8 meeting will be at Oklahoma City during the South Central Region meeting, October 1-4.

Corporate Membership Committee to Be Named

A committee will be named by NACE President W. H. Stewart to work with the firm that will solicit corporate memberships in the National Association of Corrosion Engineers.

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Subscribers to CORROSION are found in over 40 foreign countries.

T-9 on Marine Biological Deterioration to Organize at Wrightsville Beach June 11-13

C. M. Wakeman, chairman of NACE Technical Group Committee T-9 on Marine Biological Deterioration has announced that the organizational meeting for T-9 will be held June 11-13 at Wrightsville Beach, North Carolina during the 1957 Sea Horse Institute.


Wakeman

The history and background of the affiliation of the Marine Borer Group with NACE will be described by Mr. Wakeman. Advance planning indicates that the T-9 organization will include committees on preservation factors, laboratory and field evaluation of preservative treatments and related problems and bilogical aspects of wood deterioration.

On Tuesday, June 11 from 7 to 10 pm, T-9 will hold discussions on preservative factors. Chairman of this session will be Reginald Cooley with A. P. Richards, Ray Heiks and James Roche as moderators. Topics for discussion will be: How effective are: 1. Copper and zinc naphthenates? 2. Wolman salts? 3. Celcure? 4. Boliden salts? 5. Other materials in preservation of wood in marine environments? What is the present status of copper containing compounds for the preservation of marine borers? How do limnoria manage to exist in creosoted wood? What is the present information on borer resistance to barrier materials? Is there any tabulated information available giving the approximate useful life of various sized wood piles treated or coated with anti-borer materials installed in marine waters? What is the experience as to the life of creosote pilings in the South Pacific area? Are current specifications for the creosote treatment of marine piling adequate? What has been done—or is contemplated—in the way of a storage center for standard samples of preservatives?

Evaluation of Preservatives

On June 12, a session will be held on Laboratory and Field Evaluation of Preservative Treatments and Related problems. Chairman of this session is Harry Hochman. Moderators are Glen Greathouse, F. G. Walton Smith and S. Miller.

Topic for discussion will be: An illustrated outline. Marine investigations of the U. S. Naval Civil Engineering Research and Evaluation Laboratory, at Hueneme, California, by Dr. Harry Hochman. Discussion of the effect of ultrasonics and electrical current on marine organisms. What is the practice for protection of wood boat hulls from marine borer attack? Discussion of woods naturally resistant to marine borers. Role of marine fungi in the deterioration of wood. Standardization of laboratory evaluation of marine borer deterrents.

Can toxicity tests be used to evaluate marine borer deterrents? Factors involved in field testing of preservatives. Measurement of the attack upon organic materials in marine environments. What is being done to further evaluate materials which have been toxic toward marine borers in laboratory toxicity tests? What is the present idea in regard to standard populations of marine organisms for deterioration testing or research?

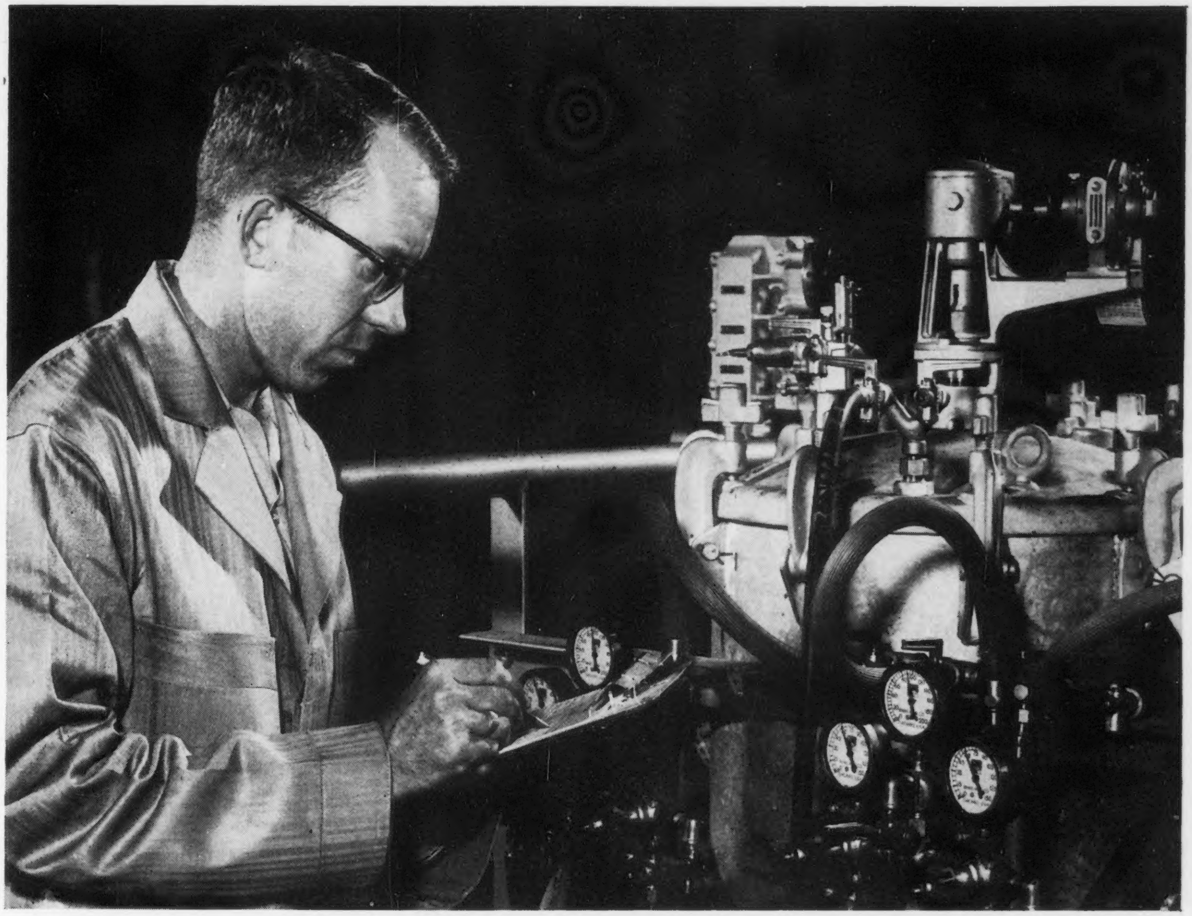
Biological Aspects Session

On June 13, a session will be held on Biological Aspects of Wood Deterioration. Chairman for this session is S. R. Galler. Moderators will be T. R. Sweeny, Carl Wessel and R. J. Menzies.

Topics for discussion will be: What's new on the physiology of marine organisms? What are latest developments on the investigation of marine borers and the effects of new sanitary systems, sewers vs. treating plants eliminating pollution? Factors governing the attack of wood by marine organisms in the larval stages. What is the present state of knowledge regarding the use of enzyme inhibitors for destroying marine borers? What is known about the biochemistry of marine borers—their food requirements? What is the effect of temperature on the boring rate of various species of limnoria?

What are the mechanisms of biological deterioration in marine environments? Is there physiological evidence suggesting that one or more species of limnoria are capable of adapting themselves to the various toxic components of creosote? Is a complete description

(Continued on Page 92)



Oxford Heads New High Pressure Well Task Group

W. F. Oxford, Jr., Sun Oil Company, Beaumont, Texas has been appointed chairman of Task Group T-1B-1 on High Pressure Well Completion and Mitigation Practices. The task group held a meeting in Houston April 23. A report on the meeting has not been received.

Oxford

Metallurgy Unit Considers Oil Well Tubing, Sweet Crude, Condensate Stress Corrosion

Two principal subjects were discussed at the meeting of Unit Committee T-1F on Metallurgy held in St. Louis, March 11. One was consideration of various factors in the corrosion of oil well tubing; the other was preparation of a questionnaire by a task group on sweet crude and sweet condensate stress corrosion cracking. The meeting was held during the NACE Thirteenth Annual Conference.

Excerpts from a report on normalizing upset tubing were read. It was recommended that H-40 tubing need not be normalized, that J-55 may be, and that N-80 and P-105 should be full-length normalized to prevent ringworm corrosion. A study is underway to determine if end-normalized tubing should be plastic coated outside and inhibitors used to prevent ringworm corrosion.

Ringworm Corrosion Effects

One member said J-55 tubing which has a 65,000 psi average yield will show about 7000 psi lower yield in the ringworm area if not full-length normalized; N-80 shows as much as 20,000 psi reduction. His opinion was that all N-80 tubing should be normalized. He said one mill adjusts chemicals to meet the 80,000 psi minimum in the heat run-out area, but this still left the ringworm corrosion problem.

A failure of 9 percent chromium tubing in a well in the Puckett Field was reported by a member. Failure was said to be caused by improper heat treatment (hardness Rockwell C-38). Some tubing broke standing in the derrick, but it was not due to stress corrosion cracking. Heavier wall and tapered strings instead of 130 to 150,000 psi yield was suggested.

Sulfide Condition Requirements

One opinion was that no higher than J-55 should be used under sulfide conditions and that operators should watch for down-graded N-80. A statement was made that some foreign J-55 checked 102,000 psi yield.

Nine percent chromium molybdenum has more C-ring ductility, it was said. Mill defects could be detected by magnetic particles and ultrasonic tests, but field damage must be considered. Two known tubing failures in Texas due to tonk marks were reported.

The statement was made that no inhibitor seems to work in carbon dioxide wells; 4340 steel shows twice the corrosion of N-80. Nine percent chromium does not corrode at all; but in Western Kansas, chromium alloys do not help.

The task group questionnaire was designed to determine how many failures have occurred due to stress corrosion cracking in sweet crude and sweet condensate and what environmental and metallurgical factors were common to all.

Full Heat Treatment Urged

It was mentioned that one company also had failures in sulfide service in Canada. In checking casing for hardness, a 96-B Rockwell maximum resulted in 50 percent rejection for this service. However, another case was cited where, with a 95-B Rockwell maximum, only 3 percent rejections occurred. It was suggested that hardness is only a rough parameter for sulfide service; and that full heat treatment (full normalizing plus adequate tempering, approximately 1100 F or 1150 F) is desirable. Welded piping should be tempered only.

Some other points brought out at the meeting were: Cracking occurs at from 25 to 75 percent of yield, depending on metallurgical characteristics of the steel. Precipitation hardening stainless steel cracks at 25 percent of yield with almost no observable corrosion. Tempered (lower yield) steel will resist cracking at 25 per-

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Four Objectives Are Set by Oil Ash Group

Four principal objectives were set for Task Group T-5B-3 on Oil Ash Corrosion at a March 11 meeting in St. Louis.

1. Define the problem (a work group for this purpose has already been appointed).
2. Prepare a bibliography.
3. Maintain case histories.
4. Exchange information with other groups.

Information on case histories and problems involving oil ash corrosion was exchanged in the discussion during the meeting. Efforts to find a single alloy immune to oil-ash corrosion has met with little success, according to a representative of a large metal company present. Reduction in corrosion rates is evident when additives are used, with magnesium oxide being the most promising additive.

Alloys with high nickel and chromium content of iron with 27 percent chromium showed good corrosion resistance provided an alkali metal was not present as a sulfate. Molybdenum exhibits exceptionally poor corrosion resistance. Sodium oxide is considered a universal solvent for presently known high temperature alloys and will attack chromium.

Four case histories of failures and efforts to combat them were presented.

1. A mercury boiler, operating at 1100 F, oil fired, experienced wasting of tubes. Aluminum oxide was added with no apparent beneficial effects. Dolomite was then added, causing a slagging problem in the furnace, but improvement in performance of the air preheater was noted (draft remained constant). A combination of dolomite and fly ash (two to one ratio) gave the most improvement.

2. In a 1500 psi, 1050 F steam plant, the 25 chromium-12 nickel tube spacers failed. The metal temperature was reported as 1100-1500 F. Dolomite was used but no significant improvement was noted. The plant is now operating on coal.

3. A pilot boiler operating at 1450 psi, 950 F steam, oil fired, experienced no serious corrosion problem, although there is a slight evidence of spacer tube (347 stainless steel) wasting. A pilot plant test conducted at 1300 F for 1000 hours (for 364 hours the vanadium content was 486 ppm with 3.5 percent sulfur) did indicate slight wastage. After addition of a magnesium oxide slurry (3 to 1), the air preheater, which previously was washed every eight weeks, no longer needs washing and the air preheater draft loss was practically constant after 400 hours with no apparent wasting of tube spacers.

4. New equipment costing $130,000 for handling additives was installed at one plant. The plant operated at 1,000,000 lb/hr., at 2400 psi, 1050 F, oil fired. This plant will use magnesium oxide as an additive at a rate of 10 tons per day. Expected cost of the additive was approximately $1000 per day.

VanDelinder Vice-Chairman Of Organic Coatings Unit

L. S. Van Delinder, Carbide and Carbon Chemical Company, South Charleston, West Virginia has been elected vice-chairman of Unit Committee T-6A on organic coatings and lining for resistance to chemical corrosion.

J. F. Richardson, Amercoat Corporation, South Gate, California, was elected secretary of T-6A. The election was recently announced by C. G. Munger, Amercoat Corporation, chairman of T-6A.

Mr. Van Delinder also is chairman of Group Committee T-6 on protective coatings. He was chairman of the protective coating symposium at the 1957 NACE Conference and co-chairman of the protective coating symposium at the 1956 NACE Conference.

T-9 on Marine—

(Continued From Page 88)

available of the very large teredos sometimes mentioned as being six to twelve feet long from such places as New Hebrides, Africa, Okinawa, etc.? New developments in the physiology of digestion by marine borers. What are the latest findings at Lake Maracaibo, Pedernales, Caripito and Amuay Bay, in regard to effect of salinity variations, effect of dredging and new tanker traffic at Lake Maracaibo?

Five Main Fields of Interest Summarized From Corrosion Products Unit Questionnaire

Five main fields of interest were selected from questionnaires answered and returned by members of Unit Committee T-3B on Corrosion Products. The five categories discussed at meetings of the committee held in St. Louis, Missouri, March 10 and 14 are:

1. Classification of reactions which produce corrosion products of definite composition.
2. Classification of corrosion products with respect to their ability to resist further corrosion.
3. Removal of corrosion products from equipment and media.
4. Diagnosis of corrosion problems by identifying the products and correlating occurrence with their properties.
5. Compilation of analytical procedures for determining chemical composition of corrosion products on various metals.

Product vs. Soil Type

In the discussion of the classification of reactions which produce corrosion products of definite composition, an interest was expressed in corrosion products of crude oil pipe lines. One member was especially interested in the composition of the corrosion product versus the type of soil through which the pipe line was passing. He explained that 95 percent of the corrosion was formed outside and 2 percent from the inside of pipe lines in sour crude oil systems. Certain techniques could be used for determining the type of corrosion attack by the appearance of the corrosion product.

Concerning the removal of corrosion products from equipment and media, there was interest in scale removal and system clean-up. A sample of iron and iron carbide from the bottom of a heating tube in a butane dehydrator was presented for inspection. The temperature of the line from which the sample was taken was 400 F under anaerobic conditions. The sample appeared to contain some reduced iron.

On the diagnosis of corrosion problems by identifying corrosion products and correlating occurrence with their properties, it was stated that identification techniques are no better than the quality of the sample of corrosion product used in the test.

Small Quantities Difficult

Identification of very small or microscopic quantities of corrosion products is often very difficult. Also those requesting the analysis often have not taken the sample properly and do not know precisely what information they want, according to one member of the committee. The suggestion was made that the use of chemical as well as mechanical techniques might be useful in collecting corrosion products.

The problem of diagnosis may be complicated by the fact that the constituent that controls the rate of corrosion may be present in only a very minor percentage. Obtaining as good a history as possible of each sample was recommended. Items to check for are: Exact location (for example, at the edge or inside a crack), a description of how the sample was taken (iron chisel, etc.), and a description of the layers or phases of corrosion products present.

In the use of polyethylene bottles for sampling corrosion products it was pointed out that water stored in polyethylene bottles has some corrosion inhibiting characteristics. These inhibitive characteristics may be due to hydroaction or to the presence of zinc stearate or zinc sulfate used in processing the polyethylene bottles.

One member of the committee reported work on developing standard analytical procedures for examination of the corrosion products of various metals. Procedures are being sought for aluminum, copper, stainless steels, mild steels, low alloy steels, lead, zinc and magnesium. Specific techniques will be recommended for each metal.

T-1F-1 Assumes Remaining T-1G Unit Functions

Dissolution of NACE Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking, and transfer of its remaining functions to Group Committee T-1F-1 on Sulfide Stress Corrosion Cracking was voted at the March 11 meeting held in St. Louis, Missouri.

T-1G members discussed various problems and experiences with sulfide corrosion. It was reported that valves in a Canadian gasoline plant failed because of structure, stresses and sulfide. Corrosion cracking in weld metal occurred which sealed the lips of bonnets and valve bodies. A stress raised shoulder was present. It was suggested that all metals, structures and sections should be carefully examined when sulfide service is involved.

Two Task Groups Formed By Unit Committee T-1K

Unit Committee T-1K on Inhibitors for Oil and Gas Wells recently formed two new task groups. These are T-1K-1 on Sour Crude Inhibitor Evaluation and T-1K-2 on Sweet Crude Inhibitor Evaluation. J. A. Rowe, Gulf Oil Company, Houston has been appointed chairman of T-1K-1 and C. C. Nathan has been appointed chairman of T-1K-2.

A. H. Roebuck, chairman of Unit Committee T-1K has announced that both task groups plan sessions prior to the next unit committee meeting at Oklahoma City during the South Central Region Meeting, October 1-4.

Metallurgical Unit—

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cent of yield. Total stress (applied plus residual) is the critical factor.

Rod Strength Significant

Cracked rods can be used in some services because not all cracks result in failure. When inhibitors are used effectively, carbon steel (1036) rods are as good as nickel-molybdenum (4600 to 4800) in corrosive service; high strength rods are not as good as low strength. A report was quoted as showing that higher initial strength reduced the breaking stress in sulfide service.

Three factors were said prequisite for cracking: Susceptible metallurgical structure, a critical stress and an endurance limit. Causes of cracking, however, have not been defined fully. There seems to be an optimum corrosion rate for hydrogen absorption. This absorption is intermittent and heterogeneous. The probability of stress corrosion cracking in Kansas wells was negligible, according to one person attending the meeting, who said he knew of no such failure there. The wells are not more than 3500 feet deep.

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Widespread and growing interest in corrosion control stems from the need to protect the ever-growing volume of metals exposed in modern industrial plants.

NACE NEWS

Chicago and Oklahoma City Exhibit Plans Ready

San Joaquin Valley Section Organized at Bakersfield

Thirty-six engineers from the area surrounding Bakersfield, California attended an organization meeting April 24 of the San Joaquin Valley Section. A petition has been forwarded to Western Region asking that the section be recognized.

R. I. Stark, Pacific Gas & Electric Co., was named chairman, Jerry P. Mitchell, Cardinal Chemical Co., vice-chairman and Robert L. Davis, Superior Oil Co., secretary treasurer.

The general discussion concerning formation of the section was led by Mr. Stark, assisted by Mr. Mitchell, who gave some of the history of NACE, advantages of membership and the nature of CORROSION magazine, while Mr. Davis described operation and function of the technical committees.

J. W. Wilt, Honolulu Oil Co. was named membership chairman while Herbert E. Rose, Superior Oil Co. will handle publicity and John Gardner, Richfield Oil Co., prepare rules and bylaws.

A second meeting is scheduled in June at which fundamental causes of corrosion will be discussed.

Summerson Is on Staff

Thomas J. Summerson, Research Chemist, Corrosion Branch, Kaiser Aluminum & Chemical Corp., Spokane, Wash. is new correspondent for CORROSION in the light metals field.

Southwestern Ohio Section, AIChE Hold Joint Meeting

A joint meeting of the AIChE and the Southwestern Ohio Section of NACE was held in Shuller's Restaurant, Cincinnati on March 11 with approximately 45 members and guests attending. George Zargan and Roy Oman presented a movie entitled, "Glass and You."

About 35 members and guests attended the April 23 meeting of Southwestern Ohio Section at which Howard D. Segool of Polyken Products Division of the Kendall Company presented a movie entitled, "On the Line."

During the business portion of this meeting, the section nominating committee read its report which nominated the following for section officers: Chairman, Sol Gleser; Vice-Chairman, W. E. Hare; Secretary, R. W. Ackerman; Treasurer, Len Wood.

It also was announced that the North Central Region meeting in 1958 will be held in Cincinnati, October 15, 16 and 17.

Industrial Coatings Topic At Detroit Section April 8

The April 18 meeting of Detroit Section was held in the Engineering Society of Detroit Building. Approximately 20 members and guests attended the meeting and heard S. L. Gajownik, Assistant Technical Director of Sherwin-Williams Company speak on Industrial Maintenance Coatings.

NOMINEES FOR NATIONAL NACE OFFICES AND BOARD OF DIRECTORS

The following persons have been selected by the nominating committee as nominees for the indicated national offices in the National Association of Corrosion Engineers and for election to the board of directors:

For President: L. L. WHITENECK, Los Angeles, Cal.

For Vice-President: HUGH P. GODARD, Kingston, Ont.

For Treasurer: A. L. STEGNER, Houston, Texas

For Director representing Corporate Members: (Two to be elected)	**L. C. WASSON, Milwaukee, Wis.** **CHAS. G. GRIBBLE, Houston, Texas**
For Director representing Active Members:	**R. McFARLAND, Jr., Chicago, Ill.**

An official notice of the report of the nominating committee will be mailed to NACE members before June 3 by A. B. Campbell, NACE Executive Secretary. Members may prepare and file nominations by petition prior to July 8. Letter ballots are scheduled to be mailed before August 26.

Regional Events Are Aiming at Well Rounded Displays

Arrangements for exhibitions to be held concurrently with meetings of South Central and North Central Regions in October are far advanced. Lists of prospects for both exhibitions have been prepared and solicitation letters forwarded. Floor plans and contracts covering both exhibitions have been approved and should be available for mailing in June. All arrangements for sale of booth space for both exhibitions are being handled by Central Office, NACE.

There are some differences in the scheduled opening hours and dates for the two exhibitions. South Central Region will open its exhibition at 10 am October 1 and close it at 5 pm October 3. North Central Region will open its exhibit at noon October 1 and close it at noon October 4.

The exhibition, committee meetings and technical symposia for South Central's gathering will be at Oklahoma City's Municipal Auditorium.

North Central Region's activities will be concentrated in the Sherman Hotel, Chicago. The Chicago meeting will be the first one at which an exhibition will be held by the region.

Inquiries concerning space reservations, prices and other details concerning these exhibitions should be addressed to Central Office NACE, 1061 M & M Bldg., Houston.

Water Inhibitors Topic At New York Meeting

At the April 18 meeting of Metropolitan New York Section, at Hotel Sherburne, New York City, approximately 71 members and guests attended a panel discussion on Inhibitors for Water Systems. The panel, moderated by Joe Montel of Hammond-Montel, Inc., was composed of George Best, Mutual Chemical Company, Division of Allied Chemical & Dye Corp.; S. W. McIlrath, Diamond Alkali Company and George F. Briggmann, Carbide & Carbon Chemicals Company. A question and answer period followed the discussion.

Next meeting of the Metropolitan New York Section scheduled May 7 at the Chi-Am Chateau in Mountainside, New Jersey, was to be another panel type discussion on Refinery Corrosion with R. W. Manuel of Socony-Mobil Oil Company of New York as moderator.

Luce Talks on Cast Epoxy Resins at Philadelphia

Walter A. Luce of the Duriron Company was scheduled to speak on "Cast Epoxy Resins for Corrosion Application" at the May 10 meeting of Philadelphia Section. Presentation of a past chairman certificate to Tom Degnan by J. Dwight Bird also was scheduled.

University of Illinois Short Course Set Dec. 9-13

Topics related to underground corrosion and cathodic protection will form a principal part of the material presented at the Third Biennial Short Course on Cathodic Protection to be given by University of Illinois. The National Association of Corrosion Engineers is cooperating with the university in presenting the course to be given December 9-13 inclusive. W. H. Bruckner, Research Associate Professor of Metallurgical Engineering is general chairman.

The course is open to graduates of previous short courses and to newcomers. Instruction will cover descriptive, theoretical, laboratory and field areas in the recognition of corrosion problems and their mitigation by means of the most modern developments in the theory and practice of cathodic protection.

Lecturers and Topics Listed

Scheduled lecturers and their subjects are:

Norman Hackerman, University of Texas, Austin—Basic electrochemistry and cathodic protection.

Marshall E. Parker, Consultant, Houston—Theoretical and empirical aspects in application and design of cathodic protection systems. He will be moderator at panel discussions on cathodic protection current supply systems and coatings.

The cathodic protection current supply panel will have the following members: Burke Douglas, Dow Chemical Co., will discuss galvanic anodes. Harry Aschan, Good-All Electrical Manufacturing Co., Oglalla, Neb., will discuss rectifiers. W. W. Palmquist, National Carbon Co. will discuss carbon anodes. The Duriron Company will have a speaker to present aspects of silicon cast iron anodes.

The coatings panel will consist of the following: W. F. Fair Jr., Koppers Co., Pittsburgh, will discuss coal tar coatings. Mel Hendrickson of Minnesota Mining and Manufacturing Co. will discuss plastic coatings. Frank Burns, Kerr McGee Oil Industries, Wynnewood, Okla. who will discuss asphalt coatings.

Operating and Managing Data

L. P. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J. will act as moderator of a panel to develop information in the field of managing and operating

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University of Illinois—

(Continued From Page 98)

corrosion mitigation systems. He also will present a survey of industry research activity in the cathodic protection field.

W. F. Schwerdtfeger, National Bureau of Standards will survey cathodic protection research activity at NBS.

Julius J. Harwood, Office of Naval Research, Washington will be banquet speaker on modern concepts of corrosion control.

Of special interest to the power and communications industry will be a panel on "Cathodic Protection of Lead Sheathed Cable, which will survey effects of deicing salts.

College Staff Participants

Participating in the program from the staff of the Engineering College of the University of Illinois will be E. C. Jordan, Head, Dept. of Electrical Engineering; Prof. L. B. Archer, mathematics of finance; Prof. H. N. Haywood, instruments laboratory and lectures and cathodic protection equipment demonstration; W. W. Lichtenberger, electrical aparatus lecture and demonstrations; Prof. M. Metzger, special problems in applications of cathodic protection; Prof. Bruckner, lectures on elements of corrosion and cathodic protection fundamentals.

The Illinois Power Company offers a field tour of its cathodic protection installations near the campus. Several films supplied by The International Nickel Co., Inc. and Ohio State University will be shown. An inspection tour of the Cathodic Protection Laboratory will be made.

An opportunity for student to ask questions will be afforded at a final round table session.

Fees and Registration

The short course fee is $50. An additional $12 is charged for attendance at the banquet and five luncheons. Local housing, other meals and transportation are not included.

Reservations for the course may be made through R. K. Newton, Supervisor of Engineering Extension 116D, Illini Hall, 725 South Wright St., Champaign, Ill. Registration is limited to 60 and should be made before November 15.

Kansas City Section Seeks Second Conference

During the business portion of the April 8 meeting of the Kansas City Section attended by 21 members and guests, some of the topics discussed were: Increasing membership, programs for future meetings, location of future meetings and the possibility of having another national conference in Kansas City. It was noted unanimously, by those attending the meeting, to support such an invitation to the board of directors.

Following the business portion of the meeting, A. C. Curtis, president of Pipecote Service Corporation, spoke on his company's method of coating pipe in place. Mr. Curtis' presentation was followed by a discussion.

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NACE's Bibliographic Surveys of Corrosion offer a convenient way to survey the world's literature on corrosion control.

Canadian Region Is Headed by Murdison

The recent Canadian Region election resulted in the following slate of officers for 1957: A. R. Murdison, Imperial Oil Ltd., Toronto 1, Ontario, Canada, director; F. W. Hewes, Canadian Protective Coating Ltd., Edmonton, Alberta, Canada, chairman; Bruce Levelton, B. C. Research Council, Vancouver 8, B. C., vice-chairman; A. H. Carr, Koppers Products Ltd., Toronto, Ontario, Canada, secretary-treasurer, and J. Stout, Canadian Equipment Sales & Service Co. Ltd., South Edmonton, Alberta, Canada, membership chairman.

Webster Is Toronto Section's New Chairman

After being elected secretary-treasurer of Canadian Region, A. H. Carr resigned as chairman of the Toronto Section and brought about the following section officer changes:

H. Webster, Corrosion Service Ltd., chairman; William Landon, Consumers' Gas Company of Toronto, vice-chairman; Frank Farrer, Trans-Northern Pipeline Ltd., secretary-treasurer; and Gordon Poole, Canadian Johns-Manville Company Ltd., membership chairman, all of Toronto, Ontario, Canada.

Carolinas Section Hears Uhlig on Current Trends

H. H. Uhlig, Massachusetts Institute of Technology spoke on Current Trends in Corrosion Control at the April 24 meeting of the Carolinas Section. Dr. Uhlig's paper covered current research and the newest thoughts in uses of alloys, design and protective coatings. There was also a discussion of the Corrosion Research Council and general agreement among the 60 members and guests attending the meeting, that industry should support it.

Central New York Section Elects Orrin Broberg

At the April 26 meeting of Central New York Section, attended by approximately 21 members and guests, held in the Hotel Woodruff in Watertown, New York the following new officers were elected effective June 1: Orrin Broberg, Lamson Corp., chairman; L. Andrew Kellogg, Niagara Mohawk Power Corp., vice-chairman, and Charles E. Ward, Johns-Manville, Dutch Brand Division, secretary-treasurer, all of Syracuse, New York.

New Industrial Water Tests Approved by ASTM

Three proposed new tentative tests for industrial water were approved for ballot by Committee D-19 on Industrial Water of American Society for Testing Materials. The tests cover methods of test for nitrite by the Rider-Mellon method, for low concentrations of iron by the phenanthroline method and for appearance properties.

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CORROSION is indexed annually in December.


Adkins


Collings


Coburn


Dravnieks


Francis


Kroon


Moorman


Rydell


VanNatta


Watkins


Wilson

Chairmen for Chicago Technical Program Named

Simmons Talks on Inhibitors At Fort Worth Meeting

E. J. Simmons of Sun Oil Company, Dallas, spoke at the April 1st meeting of North Texas Section on "corrosion inhibitors. Approximately 30 members and guests attended the meeting held at Cattlemen's Steak House, Fort Worth.

Mr. Simmons discussed evaluation of corrosion inhibitors in general and the experience of his company in particular. He has found it characteristic that test data will be erratic below a certain concentration of inhibitor and that significant data will form a "plateau" above this concentration. Goal of any test must be to find the critical concentration and the level of the "plateau." Present tests will give reproducible "plateaus" which can be compared directly with tests of other chemicals performed in the same way.

Different test methods will rate a group of inhibitors in essentially the same order, but the absolute value cannot be compared directly. The main purpose of inter-company work now in progress is to obtain a better comparative basis among test methods.

Mr. Simmons said his company has subjected 340 materials to rigorous screening tests. Thirty-eight were rated sufficiently high to warrant field test and ten survived both laboratory screening and field tests and are now is use. Most field test failures resulted from properties other than ability to inhibit corrosion.

Cast Iron Is Topic at Salt Lake Section Meeting

The April 23 meeting of the Salt Lake Section held at the Mountain Fuel Supply Company Auditorium featured a panel discussion on the relative merits of cast iron pipe vs steel pipe in water service. This was the last meeting of the section for the current season.

NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1957

Oct. 1-4—North Central Region, Chicago, Sherman Hotel. Exhibition.

Oct. 1-4—South Central Region, Oklahoma City, municipal auditorium. Exhibition.

October 23-25—Western Region. Seventh Annual Conference, U. S. Grant Hotel, San Diego, Cal.

Nov. 12-14—Northeast Region Fall meeting, Pittsburgh, Pa.. Penn-Sheraton Hotel.

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

October 5-8—Northeast Region, Somerset Hotel, Boston, Mass.

Oct. 15-17—North Central Region. Cincinnati, Ohio.

October 20-24—South Central Region. New Orleans, Roosevelt Hotel.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

June 6-7—Teche Section Short Course on corrosion. Southwestern Louisiana Institute, Lafayette, La.

October 22-23—Western Region. Corrosion Control Course (Evening Sessions) Hotel U. S. Grant, San Diego, Cal.

December 9-13—Biennial Short Course on Cathodic Protection. University of Illinois and NACE.

Nine Symposia Offer Wide Scope Of Information

Chairmen have been named for the nine symposia scheduled to be held during the meeting of North Central Region at Chicago October 1-4. Also named by E. F. Moorman, Technical Program chairman was a vice-chairman in charge of meetings of technical committees.

Those named and their symposia are:

Technical Committee Meetings—L. V. Collings, Sinclair Research Laboratories, Inc., vice-chairman.

Transportation—S. K. Coburn, Association of American Railroads.

Cathodic Protection—G. G. Wilson, Institute of Gas Technology.

Pipe Line—J. L. Adkins, Peoples Gas, Light & Coke Co.

Chemical Processing Industries—W. A. Watkins, The Duriron Co., Inc.

Protective Coatings—C. A. VanNatta, Plastic Lining Coating Co.

Refinery—Andrew Dravnieks, Standard Oil Co., of Indiana.

Water Treatment—R. G. Rydell, National Aluminate Corp.

Public Utility—H. E. Kroon, Illinois Bell Telephone Co.

Fundamentals—H. T. Francis, Armour Research Foundation.

•

Widespread and growing interest in corrosion control stems from the need to protect the ever-growing volume of metals exposed in modern industrial plants.

Officers, Committee Chairmen Report on Activities

Good Progress Made During Past Year, Statements Show

Report of W. F. Fair, Jr., Tar Products Division, The Koppers Co., Inc., Pittsburgh, president:

It is my duty and privilege to report the activities and accomplishments of NACE during the past twelve months. Definite progress and growth have been attained in several fields of endeavor.

My first duty is to announce to you the results of our annual election. All the nominees proposed by the nominating committee were elected. The new office holders and directors are: President, W. H. Stewart, Beaumont, Texas; Vice-President, L. L. Whiteneck, Long Beach, California; Treasurer, A. L. Stegner, Houston, Texas (replacing R. A. Brannon who has been treasurer since April 4, 1950).

Directors: Regional, J. B. West, South East Region; Frank Costanzo, North East Region. Corporate, R. E. Kuster, Chatham, Ontario, Canada; R. S. Treseder, Emeryville, California. Active, E. G. Brink, Marcus Hook, Pa.

Several innovations were thought desirable during the past year. One example is this business meeting. In the attempt to have larger and more representative attendance at our annual business meeting, it was decided to have the meeting at this time instead of early Tuesday morning, which has been the custom in the past, to get better attendance not only for ratification of routine business but also for ratification in a legal sense of certain matters which Mr. Brannon will later describe.

> **Important Points Are Covered in Addresses**
>
> **Highlights of the reports of NACE officers and chairmen of standing committees at the St. Louis 1957 General Business Meeting:**
>
> **Dr. Fair: Careful consideration should be given to the willingness and ability to serve of persons selected for official positions in the association.**
>
> **Mr. Brannon: A budget for 1956 originally contemplating a deficit has been converted into one with a surplus by good management.**
>
> **Mr. Campbell: The percentage of active members dropped at the end of the year appears to be decreasing.**
>
> **Mr. Van Nouhuys: Regions should look at maps of their areas for places where new sections logically should be organized.**
>
> **Mr. Noppel: Each request for an exhibition at a regional meeting should be considered on its merits by the board of directors.**
>
> **Mr. May: Sales of NACE publications continue at a high level.**
>
> **Mr. Larrabee: More than a thousand are working in one or more technical committees.**

Because of the increased amount of NACE business, it was found necessary to have several executive committee meetings during the year. As you know the officers and directors have had various pension and insurance plans for our Central Staff employees under consideration for a number of years. I am happy to report that as a result of prolonged and detailed negotiations, we have been able to put into effect an appropriate contributary pension and group type insurance plan for the employees of our Houston office.

Another reason for having more executive committee meetings concerned details and administration of a regional exhibit this year for the first time. You may remember a year ago that the budget for 1956 anticipated a deficit of over $4000. This was before any consideration was given to possible cost of initiating a pension plan during the year. In view of this grave financial outlook, the South Central Regional representatives petitioned the board of directors for permission to have exhibits at their regional meeting with the understanding that the net proceeds would revert to the association treasury. In the past, the board of directors had never approved regional exhibits. Last March, however, the board did accept the South Central Region's generous offer with the explicit understanding that this procedure would be strictly on a trial basis and would not create a precedent. Furthermore, during the year the board of directors, by action initiated in the executive committee, passed an amendment to the by-laws placing all matters of regional exhibits entirely in the hands of the board of directors and furthermore directed that all legal, contractural and financial matters concerned with regional exhibits be handled in the same manner as annual conference exhibits, namely, by the personnel of our Central Staff in Houston.

I would like to stress that one of the important reasons for permitting regional exhibits was the contention that many exhibitors in rather narrow fields were in favor of regional exhibits for concentrated effort in certain limited geographical localities. They were not interested in exhibits at a national level, especially when the annual conference and exhibit was being held in some part of the country far distant from their headquarters and operations.

As Mr. Brannon will tell you, the regional exhibit last October at the South Central Regional meeting was highly successful and the board of directors at its December, 1956 meeting expressed our gratitude to the region for the substantial contribution made to the association treasury.

Nothing has been firmly established about regional exhibits in the future. This will be a matter for future boards of directors and officers to decide. In such decisions, I am sure they will be carefully advised by our policy and planning committee under the able chairmanship of Mr. Noppel.

Other activities of the association during the past year have been healthy and varied.

The active membership interest remains high and membership is still increasing although at a somewhat slower rate than occurred a few years back.

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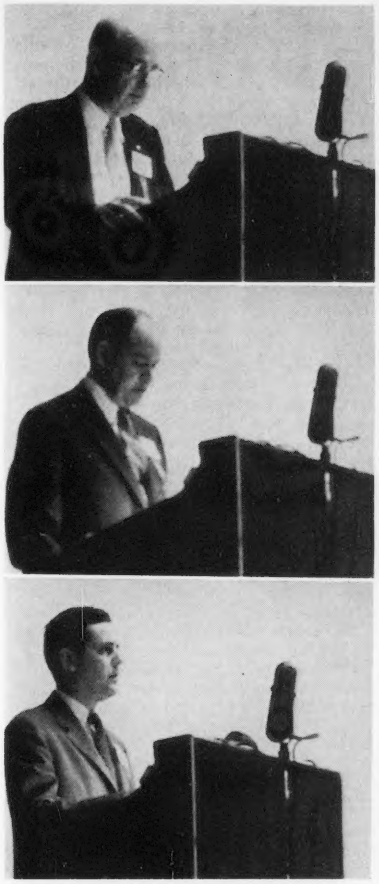


THREE OF THOSE WHO REPORTED to the NACE general business meeting in St. Louis, top, R. A. Brannon, Humble Pipe Line Co., Houston, treasurer; center, T. P. May, The International Nickel Co., Inc., New York, Publication Committee chairman; bottom: William J. Ries, Tretolite Co., St. Louis, chairman of the local arrangements committee for the 14th Annual Conference.

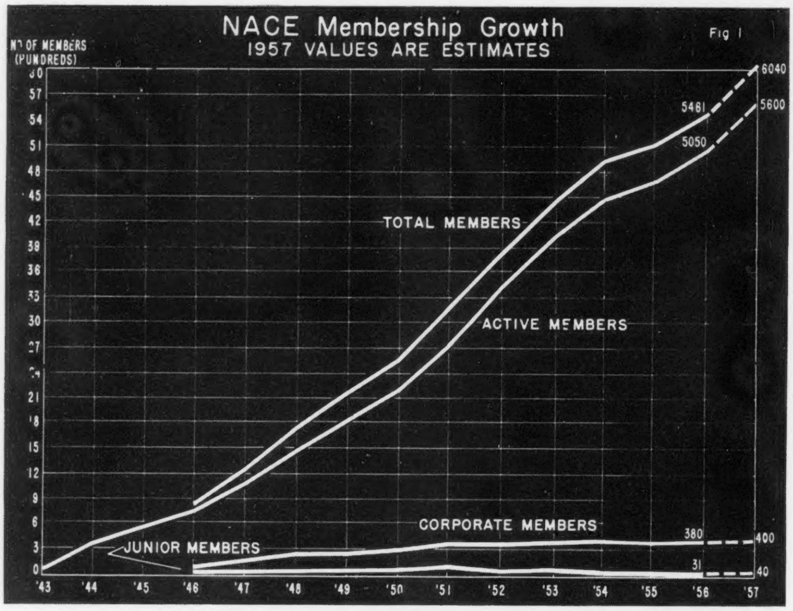
Officers, Committee—

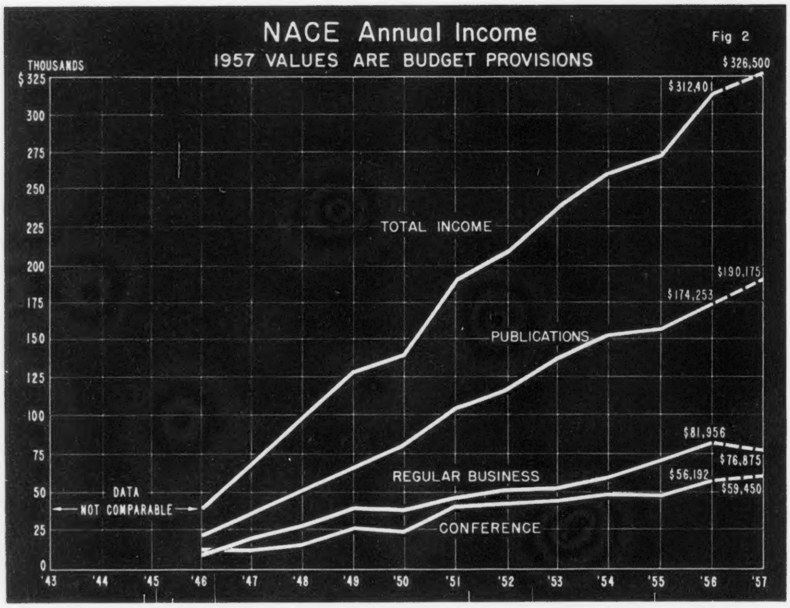
(Continued From Page 104)

Our corporate membership has, incidentally, not been increasing. It is hoped that steps now being considered will lead to a program that will catalyze the rate of increase in corporate memberships. A year ago for the first time, we had a corporate membership luncheon at which officers and corporation representatives could exchange views and suggest programs for the mutual benefit of the association and its members. The results were so encouraging that a similar luncheon was put on the schedule for this conference.

For several years, I have personally urged stronger regional organizations and if possible better regional meetings. There has been a great variation in the importance of these regional meetings. For the first time this year all the regions had regional meetings. I was able to attend three of them and I know that they were all highly successful. I understand from registrants and regional trustees that the other meetings were also entirely successful. One of the

(Continued on Page 106)





Officers, Committee–

(Continued From Page 105)

benefits of a regional meeting is the opportunity for a technical committee chairman to schedule an extra committee meeting, especially when the regional meeting location coincides geographically with a majority of the committee membership or with technical interest. Conversely having technical committee meetings at regional meetings in addition to the required one at the annual conference, increases the importance of the regional affair.

Mr. C. P. Larrabee will report briefly in a few minutes on the technical committees. Currently there has been an increase in the number of members interested in unit committees and in task groups. There is also increased interest in the formation of group committees.

It is my opinion that the current and future publication of technical committee reports, surveys and recommended practices will be one of the major factors in increased influence and prestige of NACE.

University short courses have been held as in the past few years. They are now so well organized and in many cases repeated annually in the same institutions, that the committee on education under Dr. Hackerman has little detailed work to do in this connection. I understand that all the short courses in 1956 were well attended and were considered worth attending both by the registrants and the employers who sent men to attend.

Under the guidance of Dr. Parker, Dr. May, and Mr. Hamner and their associates and reviewers, our publication CORROSION has duplicated its good performance of the past many years.

Under the economic vigilance of our executive secretary, the anticipated deficit for the year, which I mentioned above, was avoided. The affairs of the association were handled in the usual capable manner by Mr. Campbell and his loyal staff at Houston headquarters.

Now we are in the midst of another annual conference. From all the plans and reports we have received during the year and up to the last few minutes, the 1957 conference is going to be a tremendous success—technically, financially, and socially.

In conclusion, let me point out that the association's future growth depends on support from all our administrative officers and requires the diligence of the members of the board of directors and chairmen and members of standing committees in attending all meetings and performing their assigned duties. In this connection, may I offer a personal suggestion that in nominating or proposing candidates for any office, we consider geographical distribution, personal health, ability, corporate or other backing and availability both in time and expense necessary to do a good job.

NACE has established over several years a strong basis on which to grow on all levels—local, regional, and national. This continued growth of NACE must certainly embrace scientific programs, symposia and reports; stronger regional and sectional organizations; dissemination of corrosion mitigation practices; and technical advisory preeminence through committee activities and authoritative recommendations.

Report of R. A. Brannon, The Humble Pipe Line Co., Houston, treasurer:

This year's report is a favorable one because budget estimates made last year showed an expected deficit for the year's operations.

It was expected that expenses would exceed income by about $4,400. Actually income exceeded expense by $23,816.44. This welcome addition to equity may cause a feeling of satisfaction or disappointment depending upon the point of view. Financially it is fine, of course. Total income was slightly less than budget provisions so the difference cannot be explained in terms of unexpected income.

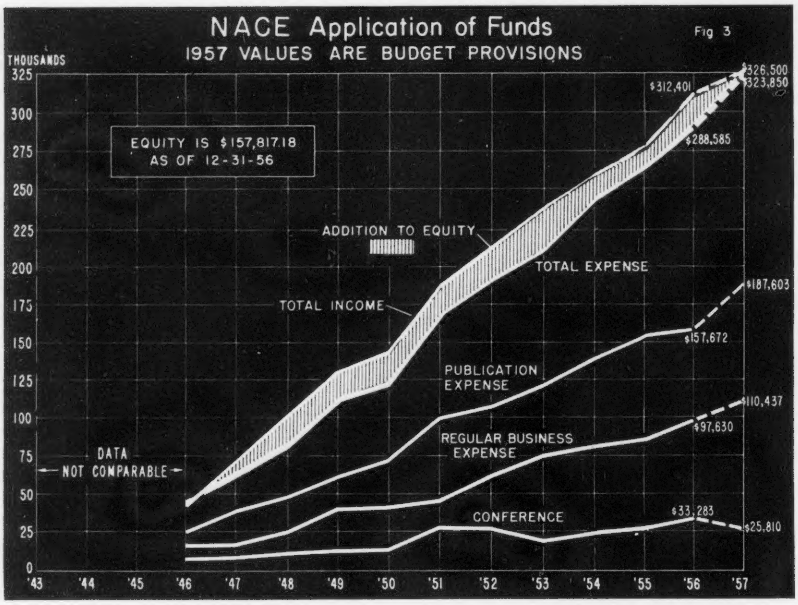
How then was the extra $28,200 realized? There were two main sources. One was lower actual expenses than the budget provided and the other was the South Central Region Exhibit which had an income of $7100 with expenses of $3100, leaving a net of $4000.

The holding down of expenses might be regarded, on the favorable side, as being the result of careful management and the use of every effort to get full value from every dollar spent. The question might be raised, however, as to whether failure to spend the money provided in the budget resulted from failure to do all the work that was planned. I am inclined to the first view and I know that much credit is due the Central Office staff and many others for accomplishing so much.

Changes in membership as shown by the auditor's report were as follows:

There were 912 additions, reinstatements and transfers of active members and 542 resignations, transfers and dropped for non-payment of dues for a net gain of 370 and a calendar year-end total of 5050. Twelve new corporate

(Continued on Page 108)



Officers, Committee–

(Continued From Page 106)

members were obtained but there were 26 resignations for a decrease of 14 to 380. Three junior members were gained but eight were lost for a year-end total of 31. The total membership at December 31, 1956 was 5461. Changes in membership since the beginning of NACE are shown in Figure 1.

Income was received from three principal sources as follows:

Regular Business	$ 81,955.74
Publications	174,253.59
Conference	56,192.00
Total	$312,401.33

Regular business income includes $7101.50 received from the South Central Region Exhibit. Figure 2 shows income for past years and budget provisions for 1957.

Operating expenses were distributed as follows.

Regular Business	$ 97,629.63
Publications	157,671.98
Conference	33,283.28
Total	$288,584.89

Expenses were $23,816.44 less than income and this was added to equity which now amounts to $157,817.18. Figure 3 shows total income and the use that was made of the funds. Budget estimates for 1957 are also shown.

The budget for 1957 provides for moderate increases in all items of income and expense except for that of expense for the 1957 Conference and Exhibitions. It appears that this conference will be quite reasonable in cost. Total income and expense are expected to come out about even with a net of $2650. The balance sheet shows that NACE is in good financial condition. Its assets are mostly current while it has few current liabilities. In any test for solvency good accountants will tell you that balance sheets like that are the best kind.

Condensed Balance Sheet
At Dec. 31, 1956

ASSETS

Current Assets	
Total	$136,367
Investments	
Shares in Savings Assns.	68,000
Special Funds	
Educational Fund	1,470
Fixed Assets—At Cost	
Office Furn. and Equip.	16,721
Less: Reserve for Dept.	10,419
Fixed Assets, Net	6,302
Deferred Expenses	5,697
Total Assets	217,836

LIABILITIES & ASSOCIATION EQUITY

Current Liabilities	
Total	1,901
Amts. Rec'd. in Advance	
Total	35,944
Revenue Deferred	
Total	20,754
Contributions for Research and Educational Purposes	
Total	1,420
Association Equity	157,817
Total Liabilities & Equity	217,836

Report of A. B. Campbell, Executive Secretary, NACE:

There are now 24 persons employed at Central Office, which is at the same location as last year. Two persons are employed part time, in addition to these. There has been a general increase in interest in corrosion studies, including short courses, interest abroad, publication in other magazines and in the starting abroad of two or three magazines dealing exclusively with corrosion.

The 1957 Exhibition occupies 141 booths sold to 108 exhibitors, exceeding the largest previous exhibit at Kansas City where 134 booths wer sold to 97 exhibitors.

Plans are well under way for the 1958 Conference at San Francisco in March. The technical program is far advanced, something we have been working toward for a number of years.

One reason for the continuing improvement in conference is that plans are being made earlier.

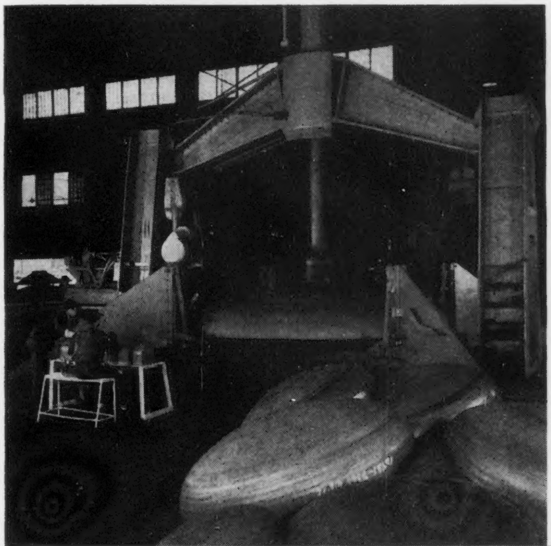
The 1959 Conference will be in Chicago; 1960 in Dallas and 1961 in Buffalo.

Membership as of December 31, 1956 was 5050 active members; 31 junior and 379 corporate members, for a total of 5460. Any discrepancy between these figures and those reported by Treasurer Brannon are the consequence of different sources of information. There was a net increase of 353 during the year. There was a net loss of 12 to 14 in the number of corporate members.

An item I have tried to report each year is the number of active members dropped at the end of the calendar year. As required by the by-laws, we dropped 274 at the end of 1956. This compares with 347 at the end of 1955, a decided improvement over recent previous years because for several years prior to 1956 the number of drops compared to the number of members held to a fairly

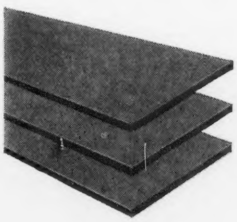
(Continued on Page 112)

ITS STAINLESS-CLAD PRODUCTS

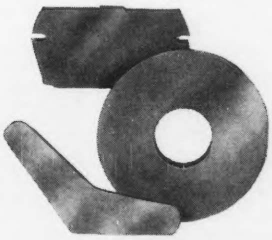


4. **Claymont Stainless-Clad Steel Heads are spun or pressed in sizes up to 19 feet and in a wide variety of shapes—flanged and dished, elliptical, conical, hemispherical, etc. Shown here are two units in Claymont's extensive head-forming facilities—a large spinning machine and a new, automatic 3000-ton press.**

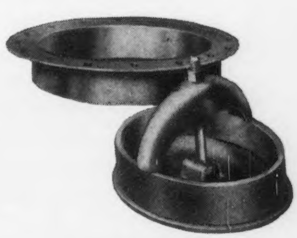
OTHER CLAYMONT PRODUCTS



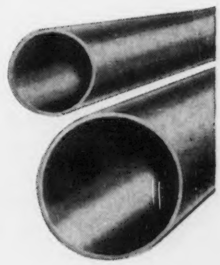
Steel Plates
Alloy • Nickel Plated •
High Strength Low Alloy



Fabricated
Steel Parts



Manhole Fittings
and Covers



Large Diameter
Welded Steel Pipe

CF&I *Claymont Steel Products*

Products of Wickwire Spencer Steel Division • The Colorado Fuel and Iron Corporation

Albuquerque • Amarillo • Atlanta • Billings • Boise • Boston • Buffalo • Butte • Casper • Chicago • Denver • Detroit • El Paso • Ft. Worth
Houston • Lincoln • Los Angeles • New Orleans • New York • Oakland • Odessa • Oklahoma City • Philadelphia • Phoenix • Portland (Ore.)
Pueblo • Salt Lake City • San Francisco • Seattle • Spokane • Tulsa • Wichita
CF&I OFFICES IN CANADA: Toronto • Montreal
CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Vancouver • Winnipeg

4440

Officers, Committee–

(Continued From Page 108)

constant ratio. This year we had more members at the end of 1956 than at the end of any previous year and our number of drops because of non-payment of dues was about 50 less.

No year book was published in 1956, but one will be published in 1957.

Other publications during the year included a 10-Year Index to CORROSION magazine, an index for all articles published from March, 1945 through December, 1954. Also published was a collection of papers by the late Dr. John Pierson on fundamental corrosion information and a Technical Committee Directory.

The board of directors also approved "Arrangements for NACE Conventions," something needed for several years to coordinate the work of local members and Central Office staff working on convention plans. Publication of a classified industrial directory is still under consideration.

An organization known as the Marine Biological Deterioration Conference has decided to come into the association so its papers may be available to CORROSION magazine and also that it may have meeting facilities. The group will be incorporated into the technical committee organization as Group Committee T-9.

As a matter of historical interest you may want to consider a few figures. When the association met last in St. Louis in 1950 there were 942 registered. At this meeting registration promises to be 2500, almost three times that of 1950.

Central Office appreciates the assistance, cooperation and support given by officers and members of NACE without whose help the association would not have made the progress it has.

Report of H. C. VanNouhuys, Southeastern Pipe Line Co., Atlanta, Ga., chairman of the Regional Management Committee:

During 1956, NACE added two new sections to its roster to continue a healthy growth. Both sections, the East Texas and the West Kansas, lie within the South Central Region which now leads with 14 sections.

The Northeast Region is second with 12 sections, while the North Central and Southeast Region are tied for third place with eight sections each. The Western Region now has six with a seventh, the Puget Sound Section in process of organization and our Canadian Region, which is the latest region, as you know, to come within NACE has five well-distributed sections. Total NACE sections are now 54.

It should be pointed out that organization of new sections within a region makes the corrosion control story available to a greater percentage of the membership and acts as a stimulus to both active and corporate membership growth.

In view of the importance of new section organization as a factor in NACE growth and in consideration of the fact that new sections have been tapering off somewhat since 1953, suggestion is made that each regional staff give some thought and action where necessary to this problem.

Approximately 400 region and section meetings were held during 1956 with an estimated total attendance of 16,000. Eight short courses were held with an estimated attendance of 2500.

In 1956 the Greater Boston and Detroit Sections joined the ranks of those sections which have over 100 membership and hence they are entitled to receive a $100 reimbursement per year in lieu of $50. Those sections already within the "over 100" category are: Baltimore, Chicago, Cleveland, Greater St. Louis, Houston, Los Angeles, Metropolitan New York, North Texas, Philadelphia, Pittsburgh, San Francisco Bay Area and Tulsa.

Approximately 50 members attended last year's Regional Management Committee meeting; and the meeting this year was held yesterday, here in Kiel Auditorium. At this meeting, the committee agreed that regional meeting conflicts are to be avoided in the future by means of each regional director advising the directors of the five remaining regions, as well as NACE headquarters, of the proposed regional meeting dates for this region.

Also, a Region and Section Activities Reporting System was set up at yesterday's meeting, which will be invaluable in more accurately estimating the degree of ativity within our association, as well as in monitoring the number of meetings, attendance, and publicity occurring within the association from year to year.

As you know, the Regional Management Committee provides an open forum for all officers of NACE to discuss any and all problems incidental to the organization and operation of the regions and sections within the association. Its purpose, through the democratic process

(Continued on Page 114)

Officers, Committee–

(Continued From Page 112)

of free speech, is to discover and recomment to the board of directors ways and means by which the association may better serve its membership.

Report of E. P. Noppel, Ebasco Services, Inc., chairman of the Policy and Planning Committee:
First a brief resume of the functions of the Policy and Planning Committee; then comments on two matters which are interesting to NACE members and which have been referred to the committee for consideration by the board.

The function of the committee is to advise the board on matters of policy referred to it by the board. It makes recommendations on long-term policy and many other matters related to policy questions in connection with the day-to-day functions of the association. It is empowered also to initiate recommendations to the board.

Two matters which have been under discussion by the committee are:

1. The matter of equity, which has grown steadily and which first had to do with holding manufacturers' exhibits in connection with regional meetings and the sale of booths for such exhibits to manufacturers. Questions raised for consideration were:

a. Will exhibits at regional meetings detract from the national meeting? Because source of equity has largely been the net from exhibitions it is very important to the association to consider this problem.

b. If regional meetings have exhibitions, should a percentage of net proceeds be allocated to the national association?

A temporary solution has been reached on this last point.

c. If manufacturers are asked to exhibit at both regional and national meetings, will this place an undue burden on them?

d. Should the Policy and Planning Committee prepare a revision of the association by-laws to provide for holding exhibits in connection with regional meetings?

The only regional exhibition held so far has been successful. Two more are scheduled this year. So far as we have been able to determine the one regional exhibition held has not affected in any way the exhibition at the national convention. What effect would result from having exhibitions at all regional meetings is unknown so the committee has recommended that the board continue to deal with each situation on an individual basis.

2. Should a limitation be placed in the amount of funds reimbursed annually to regions and sections? After a detailed analysis of the existing situation the committee has recommended that no definite limitation is indicated now. The matter will be reconsidered in 1957. The executive secretary may be asked to refer expenses he considers unreasonable to chairmen of regions or sections.

Report of T. P. May, The International Nickel Co., Inc., New York, chairman of the Publication Committee:
The Publication Committee is pleased to report a successful year in which a number of tasks were completed or reached a good position with respect to progress.

1. A Publication Policy was established which has been successful for several months in discouraging the use by other publications of preprints of papers that were presented at NACE meetings. This had previously proved to be a very troublesome matter.

2. **Bibliographic Surveys:** Sales of older volumes are continuing. The 1952-1953 survey was released in July 1956. 556 orders have been received to date. Compilation of material for the 1954-1955 survey is proceeding.

3. **Cathodic Protection Symposium** (1949): Sales of this book are continuing but at a slow rate. The NACE share of income (net) from sales to date is $2290.93.

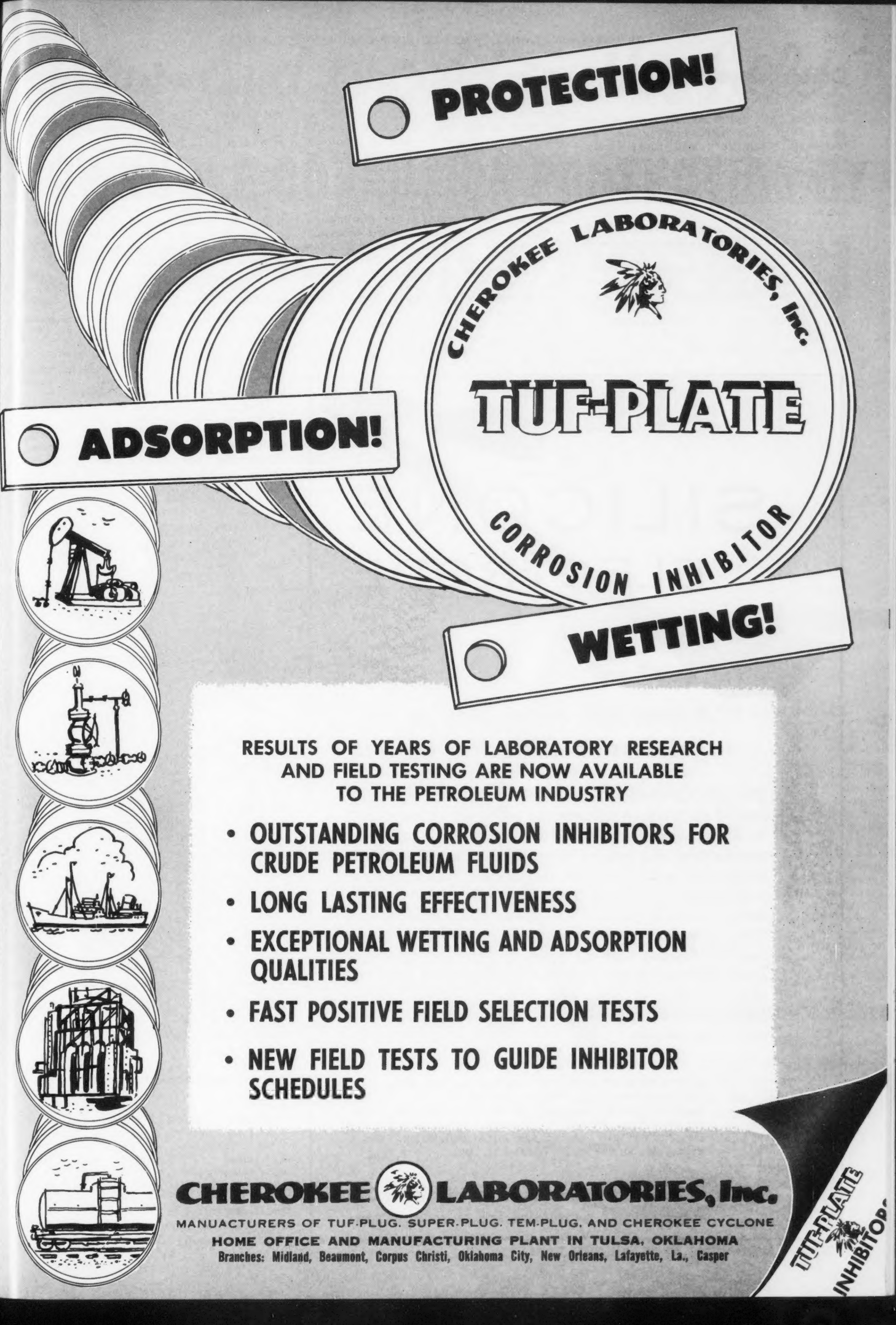
4. **Abstract Card Service:** The number of subscribers to abstract cards has shown a decline for three consecutive years as indicated in the following table.

Year	Number of Subscribers
1951	112
1952	116
1953	116
1954	111
1955	99
1956	88

This indication of diminishing interest has led to a survey of opinions from subscribers. The limitations of the card service as now being offered are being studied with the hope of developing a service that will be of greater interest and use to subscribers.

5. **Corrosion:** The year has shown an increase of 33 percent in NACE news. During the same time we have seen an increase of 18 percent in editorial material (98 pages during the year). Corrosion abstracts and technical committee

(Continued on Page 116)


PROTECTION!
CHEROKEE LABORATORIES, Inc.
TUF-PLATE
CORROSION INHIBITOR
ADSORPTION!
WETTING!
RESULTS OF YEARS OF LABORATORY RESEARCH AND FIELD TESTING ARE NOW AVAILABLE TO THE PETROLEUM INDUSTRY
• OUTSTANDING CORROSION INHIBITORS FOR CRUDE PETROLEUM FLUIDS
• LONG LASTING EFFECTIVENESS
• EXCEPTIONAL WETTING AND ADSORPTION QUALITIES
• FAST POSITIVE FIELD SELECTION TESTS
• NEW FIELD TESTS TO GUIDE INHIBITOR SCHEDULES
CHEROKEE LABORATORIES, Inc.
MANUACTURERS OF TUF-PLUG, SUPER-PLUG, TEM-PLUG, AND CHEROKEE CYCLONE
HOME OFFICE AND MANUFACTURING PLANT IN TULSA, OKLAHOMA
Branches: Midland, Beaumont, Corpus Christi, Oklahoma City, New Orleans, Lafayette, La., Casper
TUF-PLATE
INHIBITOR

Officers, Committee–

(Continued From Page 114)

activities took up about the same space as in 1955. The increasing activity of technical committees will most likely require more space as time goes on. The net gain in paid subscriptions was almost 11 percent over 1955. Gross income from advertising up 11.5 percent over 1955.

A total of 168 papers were received for review. Of these, 94 were processed and returned to the editor. Of the 94 papers, 72 were recommended for publication, 17 for rejection and 5 with no specific recommendation. The remainder are now under review. The Editorial Review Subcommittee is being expanded to reduce the time required to process papers and to lighten the burden on the individual committee members.

6. **Yearbook:** A 1957 edition of the yearbook will be published within a few months. The listing of members will be like that in the 1954 NACE Yearbook. It will be available for sale to members at cost. A single gratis copy will be given to each national, regional and sectional officer of the association.

7. **Classified Industrial Index:** A very simple and limited classified industrial index is being developed for publication in the August 1957 edition of CORROSION. This will be used as a guide for the development of a more permanent index to be published at regular intervals in the future.

8. **Acknowledgments:** In conclusion, the chairman wishes to express his sincere thanks and appreciation for the excellent support and cooperation of our editor, Dr. I. M. Parker, E. V. Kunkel and his Editorial Review Subcommittee, R. D. Misch and his Abstract Subcommittee, and the following members of the Central Office Staff: A. B. Campbell, N. E. Hamner, A. Humphries, T. J. Hull and J. T. Longino.

Report of C. P. Larrabee, U. S. Steel Corp., Monroeville, Pa., chairman of the Technical Practices Committe:

The most significant advances by the technical committees of the association during the past year include initiation of more than 50 new activities and publication of 23 technical committee reports.

Activities include formation of new committees on every level. The published reports vary in content from simple statements of progress to recommendations for material specifications. Interest of industry in these reports is clearly shown by the large number of copies of reports that have been ordered from the Central Office.

Our technical committees continue to cooperate with certain technical committees of other organizations. Several new cooperative projects were initiated during the past year and plans are under way for initiating additional projects during the ensuing year. The influence of our committees is underlined by the number of projects in which we have been asked to participate by other organizations.

There follows a brief summary of what is now underway or is being considered.

1. More than one hundred technical committee reports are being prepared.
2. Symposia sponsored by technical committees will probably be held at future regional and national conferences.
3. More committee meetings will be held at regional functions.
4. More technical committees will be organized within the local sections.
5. A new committee *may* be formed to cover the deterioration of wooden structures in marine environments.
6. A new committee *is* being formed to cover corrosion problems of the petroleum refining industry.

There is a trend in the technical committee organization to give more work to the task group level. Task groups are relatively small committees that are given a specific assignment and usually asked to complete their work in a given length of time. This method of assigning work has resulted in more responsibility for each committee member and has certainly created more personal interest in the committee work. There are currently more than 1000 individuals participating in the activities of one or more committees. This number represents nearly a 100 percent increase over the past three years. We consider this proof of the healthy growth of our committee organization.

This past year saw the culmination of the first sponsored research project supervised by a NACE Technical Committee. The project was on Sulfide Stress Corrosion Cracking, conducted at Yale University and supervised by Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. More than $20,000 solicited from industry was expended in this project and already there have been many expressions of satisfaction with the work done. It is expected the final report on the project will be published

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Officers, Committee–

(Continued From Page 116)

in the very near future. While no plans are underway for more sponsored research projects, your board of directors has appointed a research committee to consider fields where research may be desirable.

My term in office as chairman of the Technical Practices Committee expires on the last day of this conference. Mr. E. C. Greco of United Gas Corporation in Shreveport, Louisiana will succeed me as chairman, and Mr. T. J. Maitland of the American Telephone and Telegraph Company in New York City will succeed Mr. Greco as vice chairman of the Technical Practices Committe. I am sure that under the capable leadership of these able gentlemen our association can look forward both to continued growth and activity of its committees.

San Francisco Technical Program Will Include


Battle


Bigos


Binger


Brasunas


Burnett


Coburn


Erickson


Fenner


Fink


Foelsch


Foley


Gackenbach


Hugo


Hunter


Joy


Koger


Kulman


Manuel


Meyer


Ozanich


Pearl


Renshaw


Rowe


Teeple

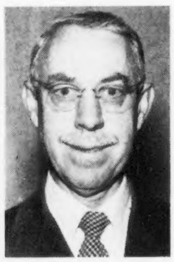

Watkins


Werner


Wilcox


Williams


Wood


Zeh

17 Symposia and Two Round Table Discussions


DeLong


Emerson


Halbig


Huddleston


McIlrath


Mercer

Tentative Technical Program for San Francisco

Monday	Tuesday	Wednesday	Thursday	Friday
MORNINGS				
	Chemical Industry	Corrosion Inhibitors	Elevated Temperature	Marine
Committee Meetings	Oil & Gas Production	Corrosion Principles	Plastics	Pulp & Paper Industry
	Protective Coatings (1)	Refinery Industry (2)	Underground Corrosion	Aircraft Industry
				General Corrosion Round Table
				Pipe Line Round Table
AFTERNOONS				
	Protetcive Coatings (2)	General Corrosion (1)	General Corrosion (2)	
Committee Meetings	Refinery Industry (1)	Chemical Industry (2)	High Purity Water	
	Pipe Line Symposium	Cathodic Protection	Utilities Industry	
	Educational Lecture	Educational Lecture	Educational Lecture	

Three New Symposia Added; Three Will Have Double Sessions In Largest NACE Program

An expanded technical program has been arranged for the San Francisco 14th Annual NACE Conference that will more thoroughly cover the corrosion control field than any previously given by NACE. Seventeen symposia are planned, including three with double sessions; two round table sessions and three educational lectures. E. D. Verink, Jr., Aluminum Company of America, New Kensington, Pa. and R. McFarland, Jr., Hills-McCanna Co., Chicago, respectively chairman and co-chairman of the Technical Program Committee, have named all chairmen.

Many of the symposia are far advanced toward completion and some are full already. Additional papers are being sought for some symposia and persons interested in presenting papers may communicate directly with the symposium chairman concerned, if they desire. Others may choose to send inquiries to Mr. Verink or to NACE Central office.

All of the technical events are in addition to the usual complement of technical committee meetings. First day of the conference is devoted wholly to committee meetings. Numerous meetings will be held during succeeding days also.

Biographical data on the two chairmen follow:

Ellis D. Verink, Jr., head of the chemical section, Development Division, Aluminum Company of America. He has been an NACE director and formerly was an officer of Pittsburgh Section. A graduate of Purdue, with a BS in metallurgical engineering, he served in the U. S. Navy at the Portsmouth, N. H. Navy Yard until December, 1945, when he joined Alcoa. He is author of several papers on chemical corrosion.

R. McFarland, secretary and technical director of Hills-McCanna Co., has for some 20 years been engaged in activities associated with the design and application of pumps, valves and allied equipment of both metallic and non-metallic materials.


McFarland


Verink

A graduate of Armour Institute of Technology's school of chemical engineering, he did graduate work in organic chemistry at University of Chicago. He is chairman of T-6A and a member of AIhE, ACS, ASM, Tappi and Mss.

Five More Editorial Committeemen Added

Five members have been added to the NACE Editorial Review Sub-Committee. These additions being the total number on the committee to 23. Of these 22 members will be occupied with review matters, while E. V. Kunkel, Celanese Corp., subcommittee chairman, will handle administration.

The additions are: Otto H. Fenner, Monsanto Chemical Co., St. Louis; W. B. Brookes, Senior Metallurgist, Materials Engineering Service, Electrochemical Engineering Dept., The Dow Chemical Co., Freeport, Texas; Marc Darrin, Associate Director of Research, Mutual Chemical Division, Allied Chemical & Dye Corp., Baltimore; A. C. Elm, Technical Dept., New Jersey Zinc Co., Palmerton, Pa. and B. C. Haworth, Engineering Dept., E. I. duPont de Nemours & Co., Inc., Wilmington.

SYMPOSIA OFFICIALS

AIRCRAFT INDUSTRY SYMPOSIUM

Chairman F. T. Wood, Jr., Chief Material Research and Process Engineer, Douglas Aircraft Co., Santa Monica Division. He has a bachelor's degree in chemistry from University of California, Los Angeles, and has done graduate work at New York University and University of Southern California. He joined Douglas Aircraft in 1941 as a chemist. He is a member of ACS, IAS, AIChE and NACE.

CATHODIC PROTECTION SYMPOSIUM

Chairman Wm. E. Huddleston, Huddleston Engineering Co., Bartlesville, Okla. After 16 years with Cities Service Company, the last 10 years doing pipeline corrosion work, he started his own private consultant and small contracting business in 1946. Since, he has done pipeline corrosion engineering work in Canada, Mexico, Cuba and most of the United States. He has a BS in electrical engineering from University of Nebraska.

Co-Chairman L. A. Hugo, Phillips Petroleum Co., is manager of his company's Corrosion Survey Branch, Engineering Dept. One of the early members of NACE, he helped organize Tulsa Section and was its chairman in 1951; a national NACE director 1951-54, and has held numerous other offices in NACE's programs. He has a BS in electrical engineering from Oklahoma A & M College and has been in corrosion mitigation work since 1938.

CHEMICAL INDUSTRY SYMPOSIUM

Chairman R. E. Gackenbach, Organic Chemi-

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SYMPOSIA OFFICIALS

(Continued From Page 121)

cals Division, American Cyanamid Co., Bound Brook, N. J. He has a BS in metallurgical engineering, Lehigh University and has been active in corrosion control work since 1950.

Co-Chairman S. W. McIlrath, Central Engineering Dept., Diamond Alkali Co., Cleveland. He has been corrosion specialist for the last three years for all Diamond plants as well as chairman of the company's alkali protective coating standardization program. His corrosion experience includes three years as liaison section on packaging tanks and parts for overseas shipment in U. S. Army's Cleveland Ordnance District and seven years as corrosion engineer at the Painesville, Ohio works of Diamond Alkali. He has a BS in ChE from Fenn College, Cleveland and during 1944-46 was in the Navy Bureau of Ordnance as cognizance officer for rocket propulsion.

EDUCATIONAL LECTURES

Chairman Frederick W. Fink, Assistant Chief of the Corrosion Technology Division, Battelle Institute, has specialized in corrosion studies since joining Battelle in 1938, much of his work being on nonferrous metals and stainless steels. He is active in the Gordon Corrosion Conference, was chairman of the Corrosion Division, The Electrochemical Society and is past chairman of NACE's T-3. His publications cover many aspects of corrosion work, his MSc from University of Cambridge, England being based on condenser tube corrosion. He has an engineering degree from Cornell and studied two years in Germany and England. He is active in NACE, ECS and the AIME.

Co-Chairman Anton de S. Brasunas, American Society for Metals, Cleveland. Mr. Brasunas, after receiving a DSc from Massachusetts Institute of Technology, pursued his interest in high temperature corrosion at the Oak Ridge National Laboratory, Oak Ridge, Tenn., as a member of the faculty of the Metallurgy Division, University of Tennessee at Knoxville and has published several papers in this field.

ELEVATED TEMPERATURE SYMPOSIUM

Chairman John Halbig, Armco Steel Corp., Middletown, Ohio. Now senior research engineer with his company, he has been doing corrosion work since 1940, except during the war when he was with the Corps of Engineers. He presently is engaged in industrial corrosion control work, including selection of materials and maintenace procedures. His numerous activities in NACE include work on the Editorial Review Sub-Committee and numerous technical committees. He has been chairman of previous technical symposia and also is active in ASM. He also works with ASTM and AISI committees on maintenance and cleaning activities. He has a BS in chemical engineering from Johns Hopkins University, Baltimore.

Co-Chairman Robert T. Foley, Corrosion Chemist, General Engineering Laboratory, General Electric Co., Schenectady. Since joining General Electric in 1948 his work has been in the field of high temperature oxidation of metals. He has a BS in chemistry from University of Massachusetts, an MS from Lafayette College and a PhD in physical chemistry from University of Texas. At Calco Chemical Division, American Cyanamid Co. he worked in physical chemistry research. In NACE he has been active in the Corrosion Products subcommittee and as chairman of the Oil Ash Corrosion task group. He also is a member of ACS and Sigma Xi.

GENERAL CORROSION SYMPOSIUM

Chairman William G. Renshaw, Supervisory Chemical Engineer, Corrosion Section, Allegheny Ludlum Steel Corp. He started work for his present employer in 1940, then spent two years in the Navy working in the electronics field. He is author of several papers on corrosion resistance of stainless steel and titanium.

Co-Chairman W. W. Binger, Assistant Chief of the Chemical Metallurgy Division, Aluminum Research Laboratory, since 1953. He joined Alcoa in 1943 and has worked chiefly on application of aluminum alloys in the chemical field. He has a BS in chemical engineering, University of Wisconsin and is author of many papers on corrosion of aluminum.

HIGH PURITY WATER SYMPOSIUM

Chairman W. L. Pearl, Manager, Chemical Engineering Unit, Vallecitos Atomic Laboratory, General Electric Co., San Jose, Cal. He joined General Electric at the Hanford Works where he was concerned with coolant chemistry problems in nuclear design. He has been with GE's commercial atomic power interests since 1945. He has a BS in chemical engineering from University of Washington and an MS and PhD from the Institute of Paper Chemistry.

Co-Chairman Sherman L. Williams, Knolls Atomic Power Laboratory. For the past four years, with his present employer he has been concerned with process design and coolant technology problems associated with nuclear power plants. He attended Cambridge, has a BS in chemical engineering from Iowa State College and an MS from Rutgers, 1951.

INHIBITOR SYMPOSIUM

Chairman S. K. Coburn, Research Chemical Engineer, Association of American Railroads, Chicago. He has been chairman of NACE's T-3A on Corrosion Inhibitors, vice-chairman of T-3C on Annual Losses Due to Corrosion, editor of the Railroad Corrosion News Letter, T-3E Railroads and was Transportation Correspondent for CORROSION 1954-56. He has a BS in chemistry, University of Chicago and an MS in chemistry from Illinois Institute of Technology. He has worked as research chemist for A. D. Little and Lever Bros.

Co-Chairman Leonard C. Rowe, Senior Research Chemist, Chemistry Dept., Research Staff, General Motors Corp. Presently chairman of the General Motors Corrosion Subcommittee, Mr. Rowe is active in NACE in T-3A and T-4D as program chairman and member of Detroit Section's executive committee. He has been Transportation Industry correspondent for CORROSION. He has a BS and MS from Michigan State University.

MARINE SYMPOSIUM

Chairman Henry P. Zeh, supervisor of the Materials Laboratory of Standard Oil Co. of California. Since joining Standard of California in 1926 he has devoted his full time to selecting construction materials for the refinery, marine and pipe line divisions of the company. He has a BS in chemistry from Stanford University and a PhD in chemistry from University of Berlin, Germany.

Co-Chairman Franklin M. Watkins, Director of the Corrosion Division, Sinclair Research Laboratories, Inc., Harvey, Ill. Since employment by Sinclair in 1946 he directed additive synthesis and formulation of petroleum products with additives, an outgrowth of his interest in transformer oils developed while employed at General Electric. He has been active in Chicago Section, in NACE technical committee work and otherwise. In April, 1955 he started work full time with the American Petroleum Institute's Committee on Transportation by Water investigating corrosion problems in tankers in its Tanker Corrosion Research Committee. He has a BS from University of Colorado.

OIL AND GAS PRODUCTION SYMPOSIUM

Chairman Jack L. Battle, Supervising Chemical Engineer, Production Dept., Humble Oil & Ref. Co., Houston. Since 1933 he has specialized in the solution of oil production corrosion problems, he is active in NACE technical committees and in API, AIME and ACS. He was educated at Southern Methodist University and University of Houston.

Co-Chairman W. C. Koger, Head, Corrosion and Oil Treating Section, Oil Production Division, Cities Service Oil Company, Bartlesville, Okla. Since 1946 when he transferred to Cities Service's Oil Production Division as corrosion engineer in the West Kansas Division, he has been active in corrosion work. Formerly he was in refinery research for the company. Active in NACE's technical committees, he also is a member of the API publication committee.

PIPE LINE SYMPOSIUM

Chairman Richard J. Emerson, El Paso Natural Gas Co., El Paso, Texas. He is a corrosion engineer with his company.

Co-Chairman Charlie D. Ozanich, Southern Pacific Pipe Lines, Inc., Los Angeles. Since September, 1956 he has been in charge of corrosion control for his employer. Previously he had spent six years in corrosion work for Standard Oil Company of California, working on pipe lines, offshore piping and tanks.

PLASTICS SYMPOSIUM

Chairman W. B. Meyer, President of St. Louis Metallizing Co., St. Louis. He has been active in NACE for many years and has been concerned with corrosion problems related to metallizing, welding and the application of plastic materials of construction.

Co-Chairman O. H. Fenner, Monsanto Chemical Co., St. Louis. Most recently General Chairman of the 1957 NACE Conference, Mr. Fenner has been active in section, technical and national affairs of NAE for many years. His current interest is in application of structural plastics to the chemical industry, but he had done a variety of corrosion control work with his company.

CORROSION PRINCIPLES SYMPOSIUM

Chairman W. C. Weast, Professor of Chemistry, Chase Institute of Technology, Cleveland. He has done extensive research into galvanic corrosion in hot water storage tanks and has been active in NACE affairs for several years.

Co-Chairman W. B. DeLong, Engineering

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SYMPOSIA OFFICIALS

(Continued From Page 122)

Dept., Experiment Station, E. I. duPont de Nemours & Co., Inc., Wilmington. He has been active in NACE affairs, including work on T-1G on Sulfide Stress Corrosion and as chairman of the Chemical Industry Symposium at the 1955 NACE Annual Conference.

PROTECTIVE COATINGS SYMPOSIUM

Chairman Norman H. Burnett, Huntington Rubber Mills, Portland, Oregon. Mr. Burnett, a chemical engineer, has had 11 years of corrosion experience in the coatings and linings field. He spent two years as technical salesman for coatings and acid proof cements.

Co-Chairman H. W. Foelsch, Senior Corrosion Engineer, A. Gusmer, Inc., Woodridge, N. J. He has done research and development work on surface preparation and application of phenolics, vinyls, epoxies and furanes. He attended Wartbury College and Northwestern University.

PULP AND PAPER SYMPOSIUM

Chairman J. M. Wilcox, Manager, Process Equipment Div., Electric Steel Foundry Co., Portland, Ore. He has been manager since 1947 of his company's process equipment division, making components for equipment in the pulp and paper industry. Previously he had worked for four years as engineer at Longview Fibre Co., Longview, Wash. and with St. Regis Paper Co., Tacoma as assistant resident and later resident engineer. He left St. Regis in 1940 to work for Electric Steel Foundry Co. on design and construction of pulp and paper industry machinery.

Co-Chairman H. O. Teeple, International Nickel Co., Inc., New York. Mr. Teeple, through 1948, was general secretary of the Tappi Engineering Division and a member of its corrosion committee, he is active in NACE, Canadian Pulp and Paper Association (Technical Section); The Electrochemical Society and American Chemical Society. He has published numerous papers on corrosion, including several related to problems in the pulp and paper fields. After receiving a BS in chemical engineering from University of Michigan, he joined Westvaco Chemical Division, Food Machinery and Chemical Corp. in 1937, working on materials specification and corrosion problems. He joined Inco in 1944, and has specialized in the pulp and paper field.

REFINERY INDUSTRY SYMPOSIUM

Chairman R. W. Manuel, Senior Corrosion Engineer, Refinery Engineering Div., Socony Mobil Oil Co., New York. His long experience in corrosion control work involves service with Crane Company's research laboratories, Chicago; Goodyear Research Laboratories, Akron; Phillips Petroleum Co., Bartlesville; Lago Oil and Transport Co., Aruba, N. I. He is a member of NACE, AIChE, ASM and ECS. He has a BS in chemical engineering from University of Kansas, 1936.

Co-Chairman Edward L. Hildebrand, Metallurgist, Humble Oil & Ref. Co., Baytown, Texas. His 12 years of experience in corrosion work includes testing, material selection, welding and metallurgical studies. He has a BS in metallurgical engineering from Missouri School of Mines and Metallurgy.

ROUND TABLE—GENERAL CORROSION

Chairman A. S. Joy, Brumley-Donaldson Co., Huntington Park, Cal. He has been active for more than 18 years in the coatings field.

Co-Chairman Joseph Bigos, Applied Research Laboratory, United States Steel Corp. He is head of the Organic Coatings section at U. S. Steel's laboratory and immediately prior to that from 1951 to 1957 was a Senior Fellow at Mellon Institute and Director of Research of Steel Structures Painting Council. From 1940 to 1948 he was engaged in the Army Transportation Corps in ship repair, and marine work including drydocking, cleaning and painting of ships. He taught chemical engineering at University of Pittsburgh from which school he has a BS, MS and PhD in chemical engineering. He is a member of AIChE, ACS, NACE, ASTM and AAAS.

ROUND TABLE—PIPE LINE

Chairman J. N. Hunter, Jr., Service Pipe Line Co., Tulsa. His work in corrosion control extends over a period of more than 10 years. He was assigned to corrosion department of Stanolind Pipe Line Co., Tulsa in 1948. He has a BS in petroleum production engineering, University of Tulsa.

UNDERGROUND CORROSION COORDINATION

Chairman C. A. Erickson, Jr., The People's Natural Gas Co., Pittsburgh, has been active in

(Continued on Page 124)

Carey

Fraser

Schillmoller

Simmons

Works

Corrosion Meter Is Topic at Chicago

A direct reading corrosion meter and its applications to inhibitor evaluation, oil well, cathodic protection, refinery and tanker testing were described at the April 16 meeting of Chicago Section, NACE. The corrosion meter employs temperature compensated probes. The talk was entitled: "An Electrical Resistance Corrosion Meter—Some Considerations in Design and Application." Technical speakers were G. A. Marsh and E. Schaschl, The Pure Oil Co., research and development laboratories, Crystal Lake, Ill.

Factors involved in pitting, reproducibility, and time required for accurate readings were discussed by the two research men. Probe design is related to the results obtained, they said. A number of laboratory and field applications were discussed with emphasis on applications in the petroleum industry. Mr. Marsh and Mr. Schaschl developed the corrosion meter and the temperature-compensated corrosion probe, and published information on it in 1955.

Fellowship hour for the meeting was sponsored by the Dearborn Chemical Co. with Carl B. Smith as senior host assisted by Wayne Shultz and Paul Payne. Master of ceremonies was M. D. Fletcher.

Central Oklahoma Section Discusses Oil Well Tubing

Donald F. Taylor of Otis Pressure Control spoke on Corrosion Detection in Oil Well Tubing at the April 23 meeting of the Central Oklahoma Section. Approximately 20 members and guests were present during Mr. Taylor's talk which was illustrated by slides showing results of calipering surveys. A calipering tool was demonstrated.

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Papers are being sought now for NACE's 1958 Conference in San Francisco.

Exhibit Plans for San Francisco Are Far Advanced

Arrangements are well under way for the exhibition to be held concurrently with the 14th Annual NACE Conference at San Francisco March 17-21, 1958. Tentative plans for the exhibit layout have been made and contracts signed with decorating and drayage concerns. George A. Works, Union Oil Co., of Cal., Exhibits committee chairman named the following members of his committee:

William P. Simmons, Alloy Steel Products Co., Inc., is in charge of auditorium arrangements. Mr. Williams, past secretary-treasurer of San Francisco Bay Area Section, is a graduate of Worcester Polytechnic Institute with a BS in chemistry. He has an MS in aerological engineering from University of California at Los Angeles.

Charles M. Schillmoller, International Nickel Co., Inc., is Los Angeles Area coordinator. He is a graduate of the University of Sydney, Australia, with a BE in chemical engineering.

John P. Fraser, Shell Development Co., Emeryville, Cal., is in charge of decorations. Mr. Fraser is a graduate of Cornell with a B. Chem E. and a PhD in metallurgy. He also is active in T-1F.

R. S. Carey, Union Oil Co. of Cal., in charge of selling arrangements, received BSE degrees in chemical and metallurgical engineering from University of Michigan.

A budget and preliminary conference plans are scheduled to be presented to the board of directors in July.

SYMPOSIA OFFICIALS

(Continued From Page 123)

the formation of NACE's T-7 in Corrosion Coordinating Committee and is its chairman.

Co-Chairman C. L. Mercer, Southwestern Bell Telephone Co., Houston, recently became vice-chairman of T-7. He is one of the first members of NACE and has been active in technical committee work.

UTILITIES SYMPOSIUM

Chairman F. E. Kulman, Consolidated Edison Co. of New York. For more than 26 years Mr. Kulman has been occupied with testing work and corrosion control with his company. His work for NACE in the field of cable corrosion and investigating the effects of street de-icing salts on underground metal plant is well known. He has been active in NACE for many years on technical committees, in New York Metropolitan Section and as an author of technical articles.

Co-Chairman Daniel R. Werner, American Telephone & Telegraph Co., Kansas City. He is in charge of cable corrosion control, Western Area for his company. He started electrolysis control work in 1934, is an engineering graduate of Rose Polytechnic Institute, Terre Haute, Ind., and has written many technical papers in his field.

GENERAL NEWS

Three Paint Courses Set at North Dakota College

Electrical Method of Hardening Steel Called "Ionitriding"

An electrical method for hardening steel surfaces involves discharge of electrical current through the materials while electrically insulated and while suspended in an atmosphere of hydrogen and nitrogen. The process, developed in Switzerland by Bernhard Berghaus, causes a high current glow discharge, especially at inside surfaces of materials treated, the inventor reports. The process, called "ionitriding" produces surface hardness and other characteristics like those of the well-known nitriding process invented by Dr. Adolf Fry.

The electrical energy accelerates gas ion streams to the extent the treated surface becomes heated and hardened by nitrogen diffusion. Dimensional changes are limited, as a rule. Gas consumption is reported low and the hardening can be accomplished in 40 to 50 hours. The process is being used to treat such parts as gears, parts with long, complicated bores and slots. Increased corrosion resistance is claimed also.

Gas Dynamics Symposium Set at Northwestern

A symposium to be held August 26-28 at Technological Institute of Northwestern University, Evanston, Ill. will have as its theme "Transport Properties in Gases at High Temperatures and Pressures." The symposium is the second of a biennial series sponsored jointly by the American Rocket Society and Northwestern University.

Object of the conference, among other things will be to define the art in theory and experiment, indicate present and future needs for research, and point up promising avenues of future research. It is designed to be of interest to engineers concerned with transfer of mass, energy and momentum.

A nominal registration fee will be charged. More information can be had from Dr. Ali Bulent Gambel, Gas Dynamics Laboratory, Northwestern University, Evanston, Ill.

Large Shaft Corrosion Is Covered in ASTM Paper

"Fretting Corrosion of Large Shafts as Influenced by Surface Treatments," by O. J. Horger and H. R. Neifert, Timken Roller Bearing Co. is one of the papers to be given during the ASTM Session on Large Fatigue Testing Machines and Their Results at Atlantic City June 18.

Numerous sessions of the ASTM 60th Annual meeting will be held June 16-20.

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The 10-Year Index to CORROSION lists 1056 authors.

BOOK NEWS

Corrosion: A Compilation. By M. G. Fontana. 240 pages, 8½ x 11 inches, cloth. January, 1957. The Press of Hollenbeck, Columbus, Ohio. Per copy, $5.95.

A collection of the columns on corrosion by Mars G. Fontana published in Industrial and Engineering Chemistry over the past ten years. Dr. Fontana has arranged the columns by chapters which essentially are an outline of a course on corrosion. The compilation will be used by Dr. Fontana at Ohio State University as a text in corrosion courses and it is recommended as assigned reading for corrosion students.

Many of the articles include corrosion data useful in industry and not readily available elsewhere. Of special interest and completeness is the chapter on testing. Usefulness of the material is enhanced by an extensive subject index.

Chapters are: Nature and Extent, Eight Forms of Corrosion, Eight Methods for Combating Corrosion, Corrosion Testing and Evaluation, Materials, Environments and High Temperature Oxidation.

Cromado Duro. (In Spanish) 285 pages, 5¾ x 8⅜ inches, cloth. By Vicente Massuet Grau. 1957. Editorial J. Monteso, Via Augusta 251-53, Barcelona (8) Spain. Price not indicated.

A condensation and summary of the world's best practice in electroplating chrome. Its function is to guide those having an interest in the specialty. The author is a member of the National Association of Corrosion Engineers.

The book is divided into four parts: Characteristics of electroplated chrome; installation and equipment; the practice of hard chrome plating; and industrial applications of hard chrome. There is a bibliography and an alphabetical index. The book is liberally illustrated and contains many tabulated data.

Rumanian Magazine Has Beryllium Extraction Article

Volume 8, No. 1, January, 1957 "Revista de Chemie" a technical periodical published at Bucharest, Rumania by the Ministry of Industrial Chemistry and the Association of Rumanian Engineers and Technicians has been received at Central Office NACE. It is in Rumanian.

Among the articles in the 72-page issue are "Extraction of Beryllium Oxide from Domestic Ores, Use of Ion Exchangers on the Metallurgy and Analytical Chemistry of the Rare Metals.

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The NACE Abstract Card Service permits semi-automatic sorting of abstracts by subject matter.

Wide Variety of Information Is Offered in Series

Three painting short courses are scheduled during the summer at North Dakota State College, Department of Paints, Varnishes and Lacquers, Fargo. They are: Paint Short Course for Beginners, July 8-19; Advanced Paint Refresher Course, July 22-August 2 and Maintenance Coatings Short Course, August 5-10.

The courses are directed by Wouter Bosch, professor and chairman of the Department of Paints, Varnishes and Lacquers at the college.

Short Course for Beginners

Consisting of 20 lectures of 75 minutes each covering chemistry of drying oils, synthetic resins, natural resins, miscellaneous filmforming materials, Pigments, solvents, thinners and dryers, formulation and applications, among other things. Ten laboratory sessions of three hours each will be held on determination of color and viscosity; preparation of varnishes; grinding, determination of drying time and other characteristics, application methods. There will be five evening films of two hours each.

Advanced Paint Refresher Course

Including lectures as indicated, in addition to other features:

Chemistry of Drying Oils, Wouter Bosch.

Drying Oils Production, Refining and Chemical Modification for the Paint Industry, Robert L. Terrill, Spencer-Kellogg & Sons, Inc. Buffalo, N. Y.

Chemistry of Alkyd Resins, Wouter Bosch.

Modern Alkyd Technology, Production and Various Applications, Eugene H. Ott, Ferbert Schorndorfer Co., Cleveland.

Chemistry and Properties of Silicone Resins, T. F. Hart, Resins, Silicones Div., Union Carbide & Carbon Corp., New York.

Role of Aminoplast Resins in the Development of Modern Baking Finishes, Charles H. Parker, Surface Coating Resins, Monsanto Chemical Co., Plastics Division, Springfield, Mass.

Acrylic Resins in Organic Coatings, William C. Prentiss, Rohm & Haas Co., Philadelphia.

Latexes for Latex Paints, Richard B. Drubel, Dow Chemical Co., Midland, Mich.

Polyvinyl Acetate Emulsions for Latex Paints and Coatings, Past, Present and Future, John C. Becker, Celanese Corp., Summit, N. J.

Pentaerythritol in Protective Coatings, Fred S. Byerly, Delaware Chemicals Inc., Wilmington, Del.

(Continued on Page 126)

Commercial Titanium Alloy Sheet Forecast by Battelle

Production of Commercial titanium alloy sheets is the goal of a program of the Titanium Metallurgical Laboratory of Battelle Institute, under a program sponsored jointly by the three armed services. A report on the first six months' work involving the production of alloys with strengths 30 to 50 percent greater than previous alloys has been made. Four alloys are currently under investigation: Ti-6Mo-3Al; Ti-4.5Al-3Mo-1V, Ti-16V, 2.5Al and Ti-6Al-4V.

The sheet rolling program is designed primarily to produce materials useful to aircraft manufacturers. After the first phase, design data will be accumulated by the Materials Laboratory of the Air Force at Wright Air Development Center. Fabrication and application data will be prepared under the direction of the Air Force Materiel Command and the Navy Bureau of Aeronautics.

Titanium Casting Progress Reported to Foundrymen

Progress on methods for casting titanium are reported by Battelle Institute. "Status of Technology for Casting Titanium," by G. H. Schippereit and J. G. Kura of Battelle and R. M. Land, presented at a May 7 meeting of American Foundrymen's Society Castings Congress in Cincinnati says there is a sound metallurgical basis for establishment of a titanium casting industry.

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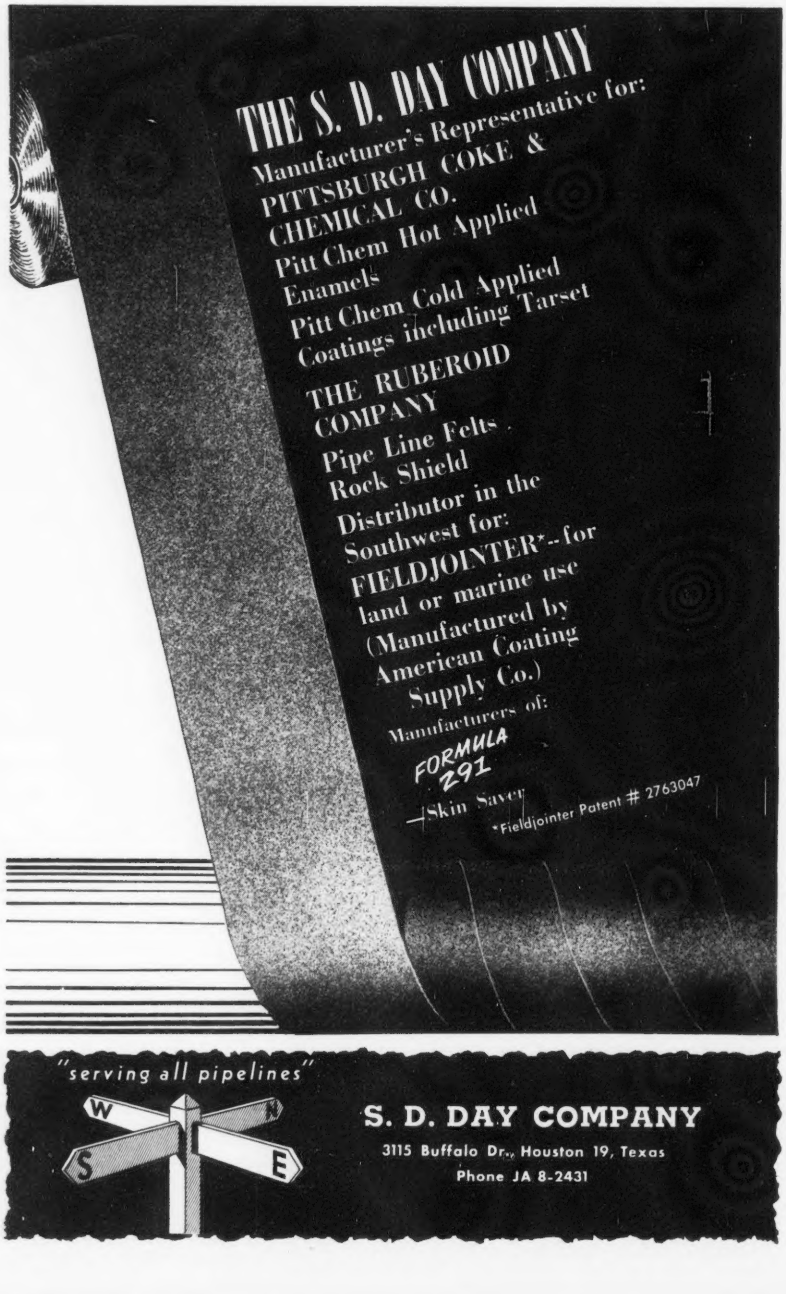
Abstracts from more than 30 sources are used in CORROSION's Abstract Section.



Sulfite Pulp Corrosion Covered in AIChE Paper

Among papers presented during the June 9-12 36th National Meeting of American Institute of Chemical Engineers were: Application of Stainless Steels for Combatting Corrosion in a Sulfite Pulp Mill, J. Kolberg, Ketchikan Pulp Co., Ketchikan, Alaska.

Paint Courses–

(Continued From Page 125)

Tall Oil—Its properties in Relation to the Protective and Allied Industries, Part 1. J. L. Slattery. **Part 2,** N. W. Craft, Newport Industries, Inc., New York.

Flushed Colors, Arthur J. Schroeder, Hilton-Davis Chemical Co., Cincinnati.

What. When and How of Paint Extenders, Payton Wheeler, Minerals and Chemicals Corp. of America, Menlo Park, N. J.

Colored Pigments, Louis A. Melsheimer, Pigments Div., American Cyanamid Co., Bound Brook, N. J.

Driers and Drier Technology, G. G. Unkefer, Harshaw Chemical Co., Cleveland.

Miscellaneous Metal Soaps and Their Use in Surface Coatings Cellulose Lacquer Finishes, Rufus F. Wint, Hercules Power Co., Cellulose Products Dept, Wilmington, Del.

Maintenance Coatings Course

Relation of Building Blocks to Properties and Performance of Coatings, Wouter Bosch.

Paint Types and Where to Use Them, Phelan-Faust Paint Mfg. Co., St. Louis.

Modern Surface Preparation to Meet Today's Industrial Needs, Modern Coatings Applications to Meet Today's Industrial Needs, S. W. McIlrath, Diamond Alkali Co., Cleveland.

General Maintenance Painting, Leland M. Wiscombe, Wiscombe Painting Co., Salt Lake City, Utah.

Researcher's View of Protective Coatings for Maintenance, V. B. Volkening, Dow Chemical Co., Freeport, Texas.

Practical Spray Painting, William R. Brooks, Binks Mfg. Co., Chicago.

Roll It On, John L. Touchett, EZ Paint Corp., Milwaukee.

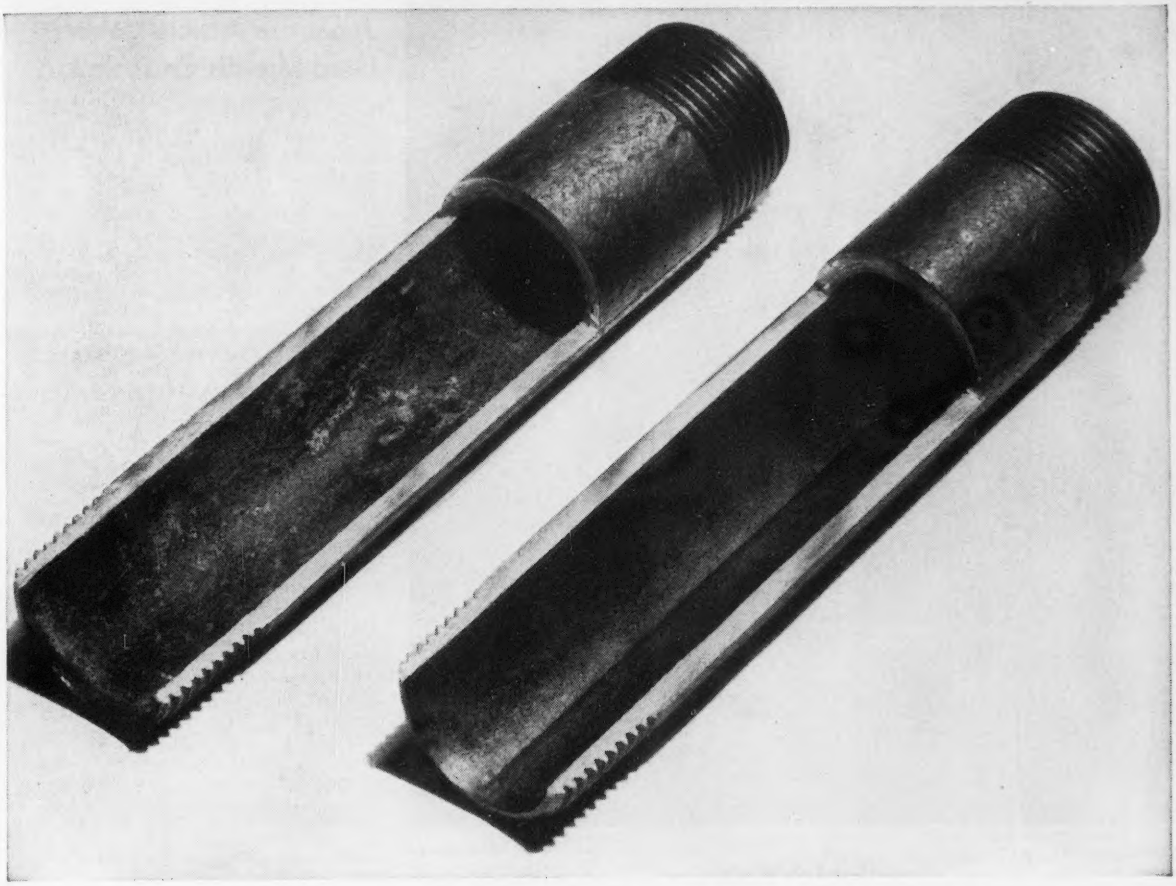
Modern Emulsion Paints—What They Mean to the Consumer, George A. Nichols, United Wallpaper, Inc., Chicago.

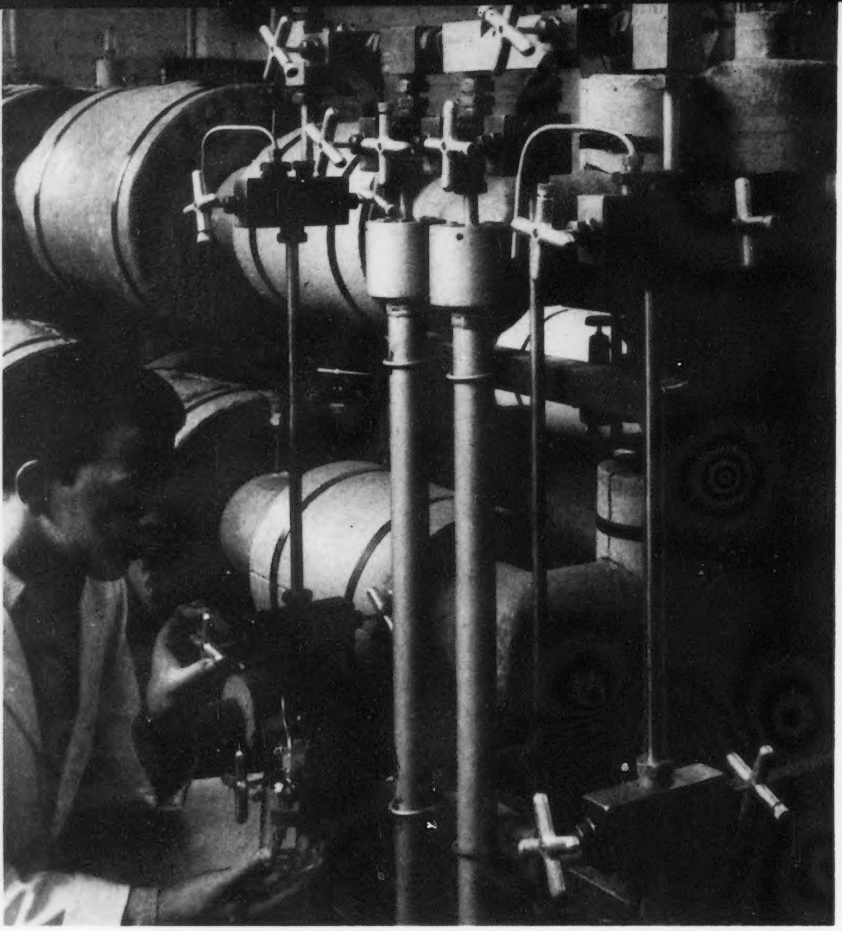
Specialty Maintenance Coatings, George B. Richardson, The Glidden Co., Cleveland.

Following is the schedule of fees for the courses: Beginners', $40; Advanced $40; Maintenance $25. Checks should be made payable to School of Chemical Technology, North Dakota State College. Applications and check should be sent to Dept. of Paints, Varnishes and Lacquers, North Dakota State College, Fargo, N. D.

Students will be accommodated on the campus at the following rates, payable after arrival: Beginners' and Advanced Courses, per student $20; for married couples, $40. Maintenance Course, per student, $14; married couples, $28.

Arrangements have been made for serving breakfast and luncheon during short course meeting days. The lecture room is air conditioned.





EXPERIMENTAL ATOMIC "TEST LOOPS," shown here were developed by Westinghouse Electric Corp., Pittsburgh to make possible pumping fluids past test specimens inside the system. Chemicals added to fluids vary corrosive effects and temperature, velocity and pressure can be controlled closely. Main function of the loops is to test effects of hot, pressurized liquids on structural materials in nuclear power plants. They operate a pressure up to 2000 psi and as high as 600 F.

Corrosion Control of Marine Tanker Is Successful

S.S. Marine Dow Chem, a 551-foot, 5 million gallon capacity tanker has been protected inside against corrosive chemicals and outside against sea water attacks since she was launched 2½ years ago. Nickel clad steel tanks carry caustic soda between 180-220 F and solid nickel piping and pumps are used. Four tanks with a capacity of 632,000 gallons, are constructed of 685,000 pounds of 10 percent nickel clad steel with nickel welds. Coils for heating, pumps, valves and piping are solid nickel or are nickel lined.

The external hull, protected by 180 60-lb magnesium anodes, has shown no corrosion except where chafed by anchor chains. Only paint on the hull is in the bow area where chains scrape the hull.

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Corrosion is indexed annually in December.

•

Abstracts from more than 30 sources are used in CORROSION's Abstract Section.

Tanker Corrosion Topic of Four Papers at API Meeting

Among the papers presented at a May 20-22 San Francisco meeting of the 1957 Annual Tanker Conference of the American Petroleum Institute's Division of Transportation were:

"Corrosion—Opinion versus Facts," W. A. Hall, Atlantic Refining Co., Philadelphia.

"A Diagnostic Approach to Tanker Corrosion," Arthur J. Coy, Engineer Superintendent, BP Tanker Co., Ltd., London.

"Modern Coatings for Tankship Compartments," W. W. Cranmer, Industrial Test Laboratory, Philadelphia Naval Shipyard, Philadelphia, Pa.

"Acid Descaling of Cargo Tanks," W. L. Miller and I. Geld, Supervising Chemists Material Laboratory, New York Naval Shipyard, N. Y.

Atom Industrialization Is Theme of Nuclear Congress

Industrialization of the Atom will be the theme of the March 17-21, 1958 Nuclear Congress at Chicago's International Ampitheater by American Institute of Chemical Engineers. Engineers and scientists in the nuclear field are invited to contribute papers, with abstracts due by June 15.

All societies connected with the nuclear field may submit papers whether or not affiliated with Engineers Joint Council.

Japanese Article Covers Lead Sheath Corrosion

Corrosion of Lead Sheath in Manhole Water by Yoshitada Yamaguchi, Hideo Miyamoto, Motoi Kusama and Tsuneo Shimozaki, engineers with Nippon Telephone and Telegraph Corporation, Tokyo gives details of tests of lead sheath materials in 45 manholes in the Tokyo area. Several conclusions were drawn from the tests respecting the influence of water composition, current density and the nature of the corrosion process.

The article, in English, is one of four in the English language edition of this periodical. Numerous items are included concerning new materials and equipment in use by the company and research in progress.

Authority Is Sought for Auto Exhaust Control

Authority as police officers is being sought from the California legislature for patrolmen of the Air Pollution Control District of Los Angeles. Until this authority is granted the patrolmen are authorized to make arrests only for violations of the Health and Safety Code, much more difficult to assess and sustain in court than motor vehicle laws against dirty exhausts.

When an acceptable exhaust control device is perfected the APCD expects to ask the legislature for laws compelling its installation. The county's 2.7 million automobiles constitute the largest single source of hydrocarbons and oxides of nitrogen which are the principal components of smog.

Wide Use of Zinc Anodes Forecast at AZI Sessions

John L. Kimberly, executive vice president of the American Zinc Institute told members of the American Hot Dip Galvanizers Association at Miami Beach April 2 that production of zinc anodes for cathodic protection uses shortly may become a significant segment of zinc industry activities. Recent research on the effect of impurities on the effective functioning of zinc anodes was cited by Mr. Kimberly.

Gillett, Marburg Lectures

The 6th Gillett Memorial Lecture to be given June 18 during the 60th Annual ASTM meeting at Atlantic City will be "A Perspective of Mo-Base Alloys," by Alvin J. Hersig, president, Climax Molybdenum Co. of Mich.

"Your Most Important Raw Material," a discussion of the importance of industrial water will be given by Everett P. Partridge, director, Hall Laboratories, Inc., Pittsburgh as the annual Edgar Marburg Lecture June 19.

Atomic Reactors Discussed

The American Society for Metals Boiler and Pressure Vessel Committee meeting held May 1-3 at the Rice Hotel, Houston considered a number of technical problems related to atomic reactors.

Industrial Chemistry Congress Session Set

The 30th International Congress of Industrial Chemistry will meet September 17-24 at Athens, Greece. Numerous divisions of technology are to be surveyed, including analytical chemistry, potable and industrial water, city sanitation, industrial application of nuclear energy, combustibles, metallurgy, organic industrial chemicals, plastics, paints, paper, dyes, sugar, agricultural chemicals and history.

Industrial Coatings Paper Is Given at Houston

"A Modern Approach to Corrosion Prevention Through Protective Coatings," by William C. Naumann, Product Development Group Leader, Shell Chemical Co., Elizabeth, N. J. was scheduled for delivery April 27 during the Southwestern Paint Convention at the Shamrock-Hilton Hotel, Houston.

Southwestern Congress

The American Society for Metals has scheduled its first Southwestern Metal Congress and Expositions in Dallas May 12-16, 1958 in the Automobile Building at State Fair Park. This show will be held on alternate years with the Western Metals Show.

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The NACE Abstract Card Service affords semi-automatic sorting of abstracts by subject matter.

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at $2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at $7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

Address Orders to

A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas

NEW PRODUCTS

Equipment Services — Materials Literature

Dittbrenner Associates, Inc., will produce and market specialty coatings. The new firm, headquartered at 18 Oneida, Rockaway, N.J. with laboratories there and in Wilmington, Del. was formed by Ray Dittbrenner and Henry W. Adams, president and vice-president respectively.

•

Electric Steel Foundry Co. has purchased a 22 million volt Betatron to complement the company's 220,000 volt x-ray and cobalt 60 radiogram facilities.

•

Minnesota Mining & Mfg. Co. has purchased the Kel-F manufacturing business from the M. W. Kellogg Co. The Kel-F facilities are adjacent to the Kellogg Jersey City plant and research laboratories.

•

Alumi-Spra, a process for adding a diffused type aluminum coating to ferrous surfaces has been developed by Chicago Metallizing Corp., 3321 South Pulaski Road, Chicago 23. The coating is designed to be especially useful on surfaces exposed to sulfides. An iron aluminum alloy bond layer is created by heat treatment at 1250 to 1325 F, sometimes in combination with stress relief treatment for welds.

•

Aluminum products for use on highways made by Kaiser Aluminum & Chemical Sales, Inc. are described in a bulletin available from the company's Highway Products Sales Office, 919 North Michigan Ave., Chicago 11.

•

Zinc as a Galvanic Anode Underwater and Zinc as a Galvanic Anode Underground, two brochures available from the American Zinc Institute, Inc., 60 East 42nd St., New York 17, N.Y. give design information for the use of zinc in the two environments.

•

Ionizing Radiation is now being used to cause mutations in genes and chromosomes in living plant cells, according to Philips Electronics, Inc. By increasing the number of mutations breeders have a better opportunity to select organisms with desirable new characteristics.

•

Onco, a composite of foil, plastic and Kraft paper is recommended by Onco Products Corp., 201 South Main St., Middletown, Ohio as a strippable coating on stainless steel surfaces. Substantial resistance to penetration by corrosives is indicated in tests.

•

Silicon Diodes capable of operation at 375 C and storage at 400 C covering a range from 100 milliamperes to one ampere have been developed by United States Dynamics Corp., 1250 Columbus Ave., Boston.

•

Dual Shield, a welding process demonstrated at a meeting of American Welding Society deposits weld metal 3 to 12 times faster than manual "stick electrode" welding and as much as 33 percent faster than established semi-automatic methods, according to National Cylinder Gas Co. A new flux core electrode permits the operator to see exactly where he is welding because the core contains the granular flux additives.

•

More Zr Facts, Vol. 1, No. 2, available from Carborundum Metals Co., Niagara Falls, N.Y. includes an article "Resistance to Corrosion Makes Zirconium Ideal Metal for Nuclear Power Reactors," by A. T. McCord, director of research for the company. Tabulated and diagrammed data are included supporting this premise. "Versatile Corrosion Resistance Gives Zr Wide Application in Chemical Processing," by W. E. Kuhn, Senior Engineer, Research and Development Div., gives specific examples of resistance to industrial chemicals.

•

Oakite Drycid, a powder rapidly soluble in water is recommended as an alternate to liquid cleaners for removal of rust, scale and corrosion from metallic objects by Oakite Products, Inc., 157 Rector St., New York 6, N.Y. Solutions of the compound cold or heated to 165 F are said to be effective. Principal advantage over liquids is ease of shipment, safety and the fact no carboys need be returned. It is said also to be safer to use on aluminum, brass and galvanized surfaces.

•

Zyglo and Zyglo-Pentrex, a 16-page illustrated manual on the use of fluorescent penetrant materials and equipment is available from Magnaflux Corp., 7300 West Lawrence Ave., Chicago 31, Ill.

•

Thermoswitch units made by Fenwall Inc., Ashland, Mass. entirely from Type 316 stainless steel are designed for corrosive service in 5 percent sulfuric acid up to 120 F, acetic acid vapors, halide solutions, alkaline solutions and others.

•

Economy Faucet Co., 12 New York Ave., Newark 1, N.J. offers a stainless steel faucet with double fluorocarbon seals and anti-flash screen. Recommended uses include solvents, chlorine free bleaches, oxidizing agents, caustic and acid solutions.

•

Na-Sul (dionyl napthalene sulfonates) inhibitors are recommended by R. T. Vanderbilt Co., Inc., 230 Park Ave., New York 17, N.Y. for use in distillate fuels, products pipe lines, gasoline, synthetic lubricants, and preservative oils. The oil soluble materials are sold as 50 percent blends in solvents such as refined mineral oil, mineral seal oil, kerosene and diesters. Manufacturers claim they are good rust and corrosion inhibitors, are hydrophobis and effective corrosion inhibitors in bimetallic systems.

•

United States Gasket Co. has been integrated into the Garlock Packing Co., Palmyra, N.Y. and will be known as United Gasket Company, Plastics Division of The Garlock Packing Co.

•

Tufline stainless steel plug valves manufactured by Continental Mfg. Co., Cincinnati 36 have Teflon sleeves. The sleeve is locked into position for high-pressure continuous sealing. Valves in sizes from ½-inch through 2 inches are available in several alloys and with screwed and flanged ends. They meet MSS-SP42 specifications.

•

Zirconium and Hafnium, a 12-page booklet available from U.S. Industrial Chemical Co., Division of National Distillers Products Corp., 99 Park Ave., New York 16, N.Y. describes the uses of these two metals. Zirconium's usefulness as a cladding and structural material in nuclear reactors and other potential uses are described, together with its principal physical properties. Hafnium's typical mechanical and physical properties cover corrosion resistance and other properties. Corrosion resistance of zirconium against typical corrosives is compared to titanium, tantalum, stainless steel and other alloys. Many data are graphed.

•

Met-L-X dry fire extinguisher power developed by Ansul Chemical Co., Marinette, Wis. now can be piped into areas where metal fires may occur and where it is impractical to use hand extinguishers. It is recommended espe-

(Continued on Page 132)

NEW PRODUCTS

(Continued From Page 130)

cially for use on fires in such liquid metals as sodium and NaK.

Olin Mathieson Chemical Corporation's Industrial Chemicals Division has started production of chlorine and caustic soda at its McIntosh, Alabama expanded plant.

All-Aluminum flatbed trailers are now being manufactured at the Trailmobile Company's Berkeley, California plant from designs developed by Kaiser Aluminum and Pacific Intermountain Express Co. They are 1000 pounds lighter than equivalent aluminum models of other design and weigh less than half of the steel version.

Titanium shafts solved a corrosion problem for Jabsco Pump Co., Burbank, Cal. Pumps used to handle ferric chloride leaked after 45 minutes' operation although numerous alloys were tried. Mallory-Sharon Titanium Corp. supplied commercially pure titanium from which shafts were fabricated. The difference in pump cost between titanium and other materials was absorbed in 90 minutes successful pumping. An all-titanium pump is now being considered.

Braze-Clad N, a silver brazing alloy on one or both sides of a pure nickel base is available from American Silver Co., Inc., 36-07 Prince St., Flushing 54, N.Y.

Bindox, made from rice oil, is offered as a coating for metal by Guardian Chemical Products, Inc., 2110 Chartres St., Houston. The material contains a natural wax and other constituents said by the manufacturers to have the ability to form a tough coating on metals and resistant to corrosives. Its high flash point (450 F) makes it especially suitable for application to hot castings.

Aluminum Cans, seamless and rigid are being made in production quantities at Aluminiumwerke Goettingen. A completely automatic aluminum can line, based on the impact extrusion process was developed there by Aluminium, Ltd., Montreal. In the process slugs of aluminum resembling silver dollars are fed into a die press and formed into a seamless can body. Labels, colors, special bottoms and other modifications and additions are made automatically. Changeover to different sizes can be made normally by three men in about two hours. Plans call for addition to the plant of a continuous casting unit in which ingots would be melted down, a continuous aluminum strip cast and slugs punched out automatically.

Coatings Parade, an illustrated periodical published by Bakelite Company, a Division of Union Carbide Corp., 260 Madison Ave., New York 16, N.Y. is directed to the executive, technical and purchasing departments of paint and varnish companies. Vol. 1, No. 1, is dated March, 1957.

Lukens Steel Company's rated ingot capacity will be increased nearly 25 percent when a current $33 million expansion program is completed.

Virco-Pet 20, a tan-colored viscous liquid, readily emulsifiable in water and soluble in acetone, ethanol, ethyl acetate, carbon tetrachloride, benzene, kerosene, mineral oil and ethylene glycol is recommended by Virginia-Carolina Chemical Corp., Chemicals Div., 401 East Main St., Richmond 8, Va. as an inhibitor of the corrosion of aluminum and steel. It can be added to protective coatings and antifreeze compounds.

Lockheed Aircraft Corp. and Anadite, Inc., 10630 Sessler St., South Gate, Cal. have developed a method of electroplating cadmium while avoiding hydrogen embrittlement. The vacuum plating method meets all military specifications of electrolytic plating such as corrosion and adherence. An almost completely uniform coating is obtained in both high and low places, inventors claim. Steel with 180,000 psi or higher maximum strength now can be cadmium plated with no danger of hydrogen embrittlement.

Union Carbide Corp. is the new corporate name of the parent corporation whose subsidiaries are well known in the corrosion control field. Carbide and Carbon Chemicals Co. is now Union Carbide Chemicals Co. and Linde Air Products Co. is now Linde Co.

MEN in the NEWS

Stanley B. Lord has been appointed senior equipment inspector, Chemical Group by Pittsburgh Coke & Chemical Co.

Albert C. Zettlemoyer, professor of chemistry and research director of the National Printing Ink Institute at Lehigh University has been selected to present the annual Joseph J. Mattiello Lecture at the 35th Annual Meeting of the Federation of Paint and Varnish Production Clubs to be held October 30-November 2 at Philadelphia.

James E. Poole, formerly general salesmanager, Keystone Asphalt Products Div., American-Marietta Co. has formed Jim Poole Construction Specialties manufacturers' representatives handling materials for the pipeline industry among others.

Daniel Summers, a veteran of 35 years' service retired April 1 as Toledo District salesmanager for Alcoa.

Charles J. Strickler has been appointed Section Head of organic chemistry in the Chemistry Department of Horizons, Inc., 2905 East 75th St., Cleveland.

William E. Glidden, formerly of Glidden Coating Co., Pitman, N.J. is now associated with Metalweld, Inc.

Vernon Halverson is now superintendent of Plastic Applicators' Odessa plant.

James Betts Smith has been named chief engineer of Alloy Precision Castings Co., Cleveland.

Ellsworth A. Stockbower has been appointed manager of New Product Sales in the Metalworking Chemicals Division, American Chemical Paint Co., Ambler, Pa. He joined ACP's research laboratory staff in 1947.

John Mackesy, an employe since 1939 and representative of Oakite Products, Inc. in San Francisco has received the company's 1956 David C. Ball Award for Distinguished Oakite Service.

Eugene Sinnett has been appointed general manager of Corrulux Division of the LOF Glass Fibers Co.

O. B. J. Fraser, assistant manager of Inco's Development and Research Division in New York has been awarded

(Continued on Page 133)

MEN in the NEWS

(Continued From Page 132)

honorary membership in the American Welding Society.

•

William M. Combs has been named vice-president of the Gulf Division of the Walworth Company.

•

Troy R. Stilley has been named general manager of the Electrical-Mechanical Division of Good-All Electric Mfg. Co., Ogallala, Neb.

•

M. M. Bowen has been elected to the board of directors of General Paint Corporation. He is vice-president and general manager of the Hill-Hubbell Division of General Paint and has been with the firm since December, 1930.

•

S. D. Strauss, vice-president of American Smelting and Refining Co., New York has been elected president of American Zinc Institute.

•

Fred Fulforth, for a number of years representative of United Chromium and its successor Metal & Thermit Corp. in the Philadelphia area is now located at the Southeastern Region office of Metal & Thermit, 565 Western Ave., N.W., Atlanta, Ga.

•

Bernard J. Conway has been made manager of General Alloys Company's Philadelphia District.

•

Robert W. Hale has joined Rowe products, Inc., Niagara Falls, N.Y. as a member of its protective coatings committee. Mr. Hale will live at Parma Heights, Ohio.

•

Hermann K. Intemann has been appointed president of Electro Metallurgical Co. Division of Union Carbide Corp.

•

Glenn W. Geil, a metallurgist at the National Bureau of Standards has been awarded the Department of Commerce Silver Medal for Meritorious Service. He is a specialist in low temperature research.

•

R. Worth Vaughan has been named president of American Smelting & Refining Co., succeeding Kenneth C. Brownell, now chairman of the board.

•

Charles R. Wirshing has been named Metalworking Chemicals salesmanager, West Coast District by American Chemical Paint Co., Ambler, Pa. He lives at Los Altos, Cal.

•

Austin S. Joy has been appointed manager of the Tube and Steel Division of Brumley-Donaldson Co., Huntington Park, Cal. He is chairman of NACE's T-2K committee on asphalt pipeline coatings.

Technical Writing Is Topic

A number of papers concerning the relationship between technical writers and librarians were scheduled during a symposium sponsored by the Metals Division, Special Libraries Association at Boston. The symposium was held May 27 during the May 26-31 Annual Special Libraries Association Convention at Hotel Statler.

Corrosion Toll Heavy on Railroad Rolling Stock*

Estimated Damage In 1953 Is Over $400 Millions

During 1953 the estimated cost of rehabilitating equipment damaged by corrosion cost railroads in the United States an estimated $410 million*. Railroad rolling stock, exposed to varying climatic conditions and to attacks of corrosive ladings, must nevertheless be kept in safe operating condition. Other equipment also suffers damage.

Some means are available to reduce corrosion damage. For example, inhibitors added to icing salt in refrigerator cars at a cost of $1,500,000 a year could make an estimated saving of about $10 millions by reducing corrosion of refrigerator cars, rails, fastenings and bridges from brine drippings. About 130,000 refrigerator cars with ice bunkers are in service. Of these about one-fourth are in brine service using about 3,650,000 tons of brines a year.

Portion of Repair Costs Due to Corrosion

	Percent
Passenger coaches	25
Baggage cars	40
Passenger and baggage cars	35
Mail and baggage cars	33
Hopper cars	64
Gondola cars	58
Box cars	19
Flat cars	8
Locomotives	10

Estimated* Corrosion Damage in 1953

Freight equipment	$222,000,000
Passenger cars	62,000,000
Locomotives	56,000,000
MofW equipment	70,000,000
TOTAL	$410,000,000

The advantages of building cars of corrosion resistant materials are recognized by the railroads. For example, one Eastern railroad's all stainless steel passenger cars have been in high speed service for almost 20 years and are structurally as sound today as when they were bought.

The advantage of using high-strength low alloy steel for open cars has been explored to some extent. Life in open cars may be extended at least 50 percent when it is used bare and durability of paint on these steels was found to be superior to that on ordinary steels.

Initial cost of a 70-ton hopper car using high-strength low alloy steels is $240 more than for copper-bearing steels and heavy repairs at the end of 18 years would cost about $1840. A car of the same size made from less costly copper-bearing steel would need rebuilding after 12 years and again after another 12 years for a total repair cost of $3200 for its noraml life span. Thus, the saving in using the high-strength low-alloy steel versus the cheaper material would be $1120 per car without considering possible increases in rebuilding costs. Savings of this order have induced railroads to build more than 200,000 freight cars of the high-strength low-alloy steels.

★ Digested from "Corrosion—A $400,000,000 Millstone to the Railroad Industry," by J. W. Crossett, *Modern Railroads*, December, 1955.

*In order to calculate the railroads' expenditures due to corrosion for a one-year period, the percentages above were applied to the total maintenance of equipment costs developed by the I.C.C. for 1953 which was the latest year for which these figures were available.

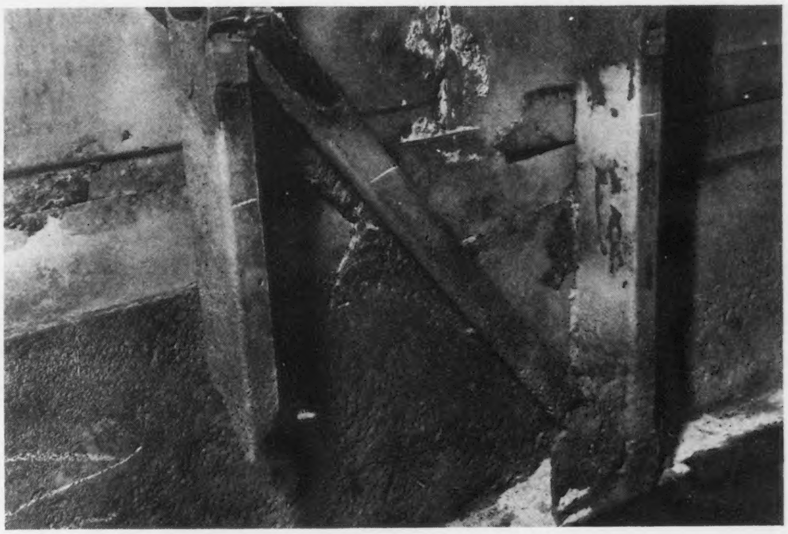

Figure 1—Corroded sills and posts in a modern diner.

Figure 2—Severe corrosion found at slope sheet ridges on common hopper cars.

MORE TECHNICAL DATA

Technical articles of timely interest will be carried under the heading "Technical Topics" to supplement information in other parts of CORROSION. This will make it possible to publish more quickly papers containing information of immediate practical value for corrosion workers. Condensed reprinted articles also will be used as space permits.

Thin Walled, High Stressed Pipe Needs Protection★

Good Design and Inspections Help Limit Damage

Abstract

Thin-walled highly stressed line pipe needs protection against initial corrosion. Ways to design a system that will prevent accidental holidays, contacts with foreign metallic structures and avoid many future contacts are described. Means of checking coating holidays shortly after backfill and before repaving are outlined. Difficulty of finding anode drainage beds in urban areas is mentioned. 8.9.3

NEW THIN-WALLED line pipe such as the American Petroleum Institute 5LX-42 and 5LX-52 specifications, which has no corrosion allowance and which customarily is stressed within 60 to 70 percent of yield point should be protected against initial corrosion.

Some of the design factors important to remember in connection with the installation of an underground pipe line, especially one in an urban area are:

1. Coatings systems should have not less than 100,000 ohms per square foot initial resistance.
2. Savings on coatings materials or application methods usually are on the order of 10 cents per foot of 16-inch pipe while savings in the cost of material of the 43-pound per foot 5LX-52 pipe versus a 63-pound per foot standard line pipe is on the order of $2 a foot.
3. Contacts with other metallic structures are a principal reason a line's current requirements are larger than theoretical.
4. Buried insulating flanges should be avoided whenever possible, a line current measuring span adjacent to an insulating flange provides a simple check method to determine if the flange is actually insulating.

★ Presented at a meeting of Western Regional Division, Long Beach, Cal., November 16-17, 1956 under the title "Pipeline Construction Practices for Economical Cathodic Protection," by C. E. Hedborg, Union Oil Company of California, Brea, Cal.

Beware of Casing Contacts

Accidental contacts between pipe and casing underneath roads or railways are troublesome. Pipes not resting on insulators will settle into metallic contact with the casing; the coatings cannot be relied on to maintain separation.

Best way to prevent accidental contacts is to clearly indicate in the contract what the owner expects the contractor to do and not to do. For example, maintenance of minimum clearances of 8 inches over or under cross lines and 12 inches between parallel lines will help prevent accidental contact.

In congested areas where these clearances are impractical, water-proof phenolic fiber laminate blocks make satisfactory insulators.

While most pipeline contracts specify minimum 30-inch cover, in the interest of avoiding accidental contacts with other lines, sometimes a greater depth may be desirable. In urban streets, for example, lines frequently will lie parallel to gas and water distribution lines. Service connections between gas or water lines and new buildings frequently are bored or driven into position. This method, while inexpensive, often results in accidental contact between the lines and service pipe. Burying a line 12 inches below existing utility lines helps prevent this accidental contact.

Insulators should be installed in casings at intervals of 15 to 20 feet throughout the casing run and as close as possible to each casing end. If the insulator is three or four feet back from the end, soil pressure will deflect the unsupported pipe and force it into contact with the casing. Casing end seals usually are not designed to be load bearing and when pipe is deflected these seals are destroyed and permit ground water to enter the casing.

One useful precaution with pipe installed in casing is to make a continuity check between the pipe and casing with a welding generator. If no arc results, an open circuit condition exists. This test must be made before the section in the casing is welded to remainder of the line.

Contacts Drain Current

Accidental contacts impose a parasitic demand on cathodic protection current. One casing contact, for example, might consume half an ampere. In cities, where casings are required at frequent intervals, the cumulative effect could overtax the capacity of a protection installation.

Pearson surveys after backfilling have been found a practical way to check coating continuity. When contract clauses stipulate that holidays traced to faulty handling or workmanship shall be repaired at contractor's expense, the clause has the effect of transferring the burden of coating inspection from the owner to the contractor.

Because Pearson surveys must be made before pavement renewal, this means that they must be made in some cases within a day after backfilling. In spite of this short interval the writer's company has been successful in finding large and small coating breaks by this method, contradicting the normal assumption that six months is required for soil moisture to penetrate to the pipe through coating.

Anode Sites in Urban Areas

It is becoming increasingly difficult to find anode sites in urban and suburban areas. The recent urbanization in Southern California communities has required the abandonment of some drain stations. A good coating plus sound construction practices should insure a 20 to 30-mile spread of protection and thereby minimize the need for drain stations where rights-of-way are difficult to obtain.

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Widespread and growing interest in corrosion control stems from the need to protect the ever-growing volume of metals exposed in modern industrial plants.

Structural Plastics' Successful Use Emphasized★

Engineering Data Make Successful Use Feasible Now

Abstract

Sixteen case histories are cited to show some of the many ways in which plastics can be used in the chemical industry. Considerable general application information is given. Some 29 plastics are given relative ratings with respect to their: 1) Resistance to temperature, 2) Resistance to weather, 3) Resistance to solvents, 4) Resistance to salts, 5) Resistance to alkalis, 6) Resistance to water, 7) Resistance to acids, 8) Cost, 9) Strength, and 10) Ductility. 6.6.8

IT IS UNREALISTIC to consider those who advocate the use of plastics in the chemical industry either pioneers or prophets. Case histories are available, showing 10 and 20 years successful use of plastics as protective coatings, linings, mortar cement, pipe, ductwork and equipment. Some of this information is summarized in the accompanying Table 1.

Before listing a few pertinent case histories, it is in order to mention a monumental work now being undertaken by committee T-5D of National Association Corrosion Engineers on Plastic Materials of Construction.

The subcommittee on engineering design has proposed the development of a type numbering system of identification based on a decimal system. As shown in the accompanying Table 2, thermoplastic and thermosetting materials are classified under Type Numbers 1-499 and 500-999 respectively. This system should be of tremendous assistance to the engineer who is interested in standardization and uniformity in specifications for plastic materials of construction.

★ A revision of a paper presented at a meeting of North Central Region, National Association of Corrosion Engineers, Detroit, Mich., November 15, 1956 under the title "Plastic Applications in the Chemical Industry." R. B. Seymour, Loven Chemical of California, Newhall, Cal. is the author.

Case Histories

The following case histories should prove of interest:

Case 1. A lead lining in an alum tank which developed pinholes was repaired with an epoxy mortar cement. The vessel is still in service after two years.

Case 2. A concrete slab which had been destroyed by nitric acid drippings was repaired through the use of a silicate cement. This surface was covered by a highly plasticized sulfur cement to protect the silicate cement from moisture. The structure (which was condemned a year ago) is still in use.

Case 3. An inexpensive chemical resistant 12-inch pipe was constructed as follows: 15 mil calendered Type I PVC sheet was wrapped around an expandable mandrel and cemented by rubbing with tetrahydrofuran solvent. The structure was reinforced with wire mesh and coated with an epoxy cement. The complete unit was wrapped with polyethylene tape. This pipe has been carrying plating plant waste satisfactorily for nine months.

Case 4. A badly corroded concrete floor subject to hydrochloric acid spillage was built up with a silicate cement. An epoxy-Thiokol cement was then trowelled on the surface to provide a chemical resistant surface capable of handling light traffic.

Case 5. Voids between tile and reaction vessels were filled with a Thiokol cement. This installation was satisfactory after 11 months.

Case 6. The inside of a hot water tank was lined as follows: One layer Portland cement, one layer epoxy cement, one layer Portland cement. The tank is performing satisfactorily after 8 months' service.

Case 7. A liner was formed from 20-mil high density polyethylene sheet by thermal welding. This form was inserted in a 1000 gallon phosphoric acid tank. An inspection after 50 days indicated that the unit was satisfactory.

Case 8. A thin walled polyethylene pipe was inserted in a stainless steel pipe which had failed in acid service. After five months, the composite structure is performing satisfactorily.

Case 9. A stainless steel clad tank used to store dilute chlorine dioxide developed leaks after three weeks' service. The holes were patched with catalyzed polyester cement. Glass cloth impregnated with a catalyzed polyester was

(Continued on Page 140)

TABLE 1—Applications

NACE No.	MATERIAL	APPLICATIONS					
		COATING	LINING	CEMENT	DUCT WORK	PIPE	EQUIPMENT
100.0	Sulfur	...	...	Hot melt	...	...	...
100.1	Polyethylene, low density	Hot spray	Insert sheet	...	Supported	Coiled	Lined
100.2	Polyethylene, high density	Hot spray	Insert sheet	...	Self supporting	Sections	Vessels, blowers
	Asphalt	Solution or hot melt	Hot melt	Hot melt	...	Impregnated fibre	...
	Coal Tar Pitch	Solution or hot melt	...	Hot melt	...	...	...
	Coumarone-indene resin	Solution or hot melt	...	...	...	...	...
	Styrene rubber blend	Solution	...	...	Self supporting	Sections	Special
1.0	Polymethyl methacrylate	Dispersion or solution	Insert sheet	...	Self supporting	Sections	Vessels
205.1	Polyvinyl chloride, plasticized	...	Adhered sheet	...	...	Coiled	Lined, gaskets
205.0	Polyvinyl chloride, rigid Type I	...	Insert sheet	...	Self supporting	Sections	Vessels, pumps, blowers, hoods
	Polyvinyl chloride, rigid Type II	...	Insert sheet	...	Self supporting	Sections	Vessels, pumps, blowers, hoods
206.0	Vinyl chloride acetate copolymer	Solution	Adhered sheet	...	...	Coiled	...
200.0	Polyvinyl acetate	Dispersion	...	Latex mix	...	...	...
250	Saran	Dispersion or solution	Adhered sheet	...	Self supporting	Coiled tubing sections	Special
300	Polytetrafluoroethylene	Dispersion	Insert sheet	...	Thin supported sections	Tubing	Gaskets, special
800	Silicone	Solution	...	...	...	...	Gaskets
50	Nylon 6, 6	Melt	...	...	...	Sections	Special
650	Polyurethene	Solution	...	...	...	...	...
	Natural rubber	Dispersion or solution	Adhered sheet	Latex mix	Flexible duct	Coiled	Gaskets
	Chlorinated rubber	Solution	...	...	...	...	...
102	Chlorosulfonated Polyethylene	Solution	Adhered sheet	...	...	Coiled	...
	Neoprene	Dispersion or solution	Adhered sheet	Latex mix	...	Coiled	Gaskets
150	Polysulfide rubber	Solution	Paste	Accelerated mortar	...	Coiled	Gaskets
70.1	Cellulose acetate	Solution	...	Powd.-liq. mortar	...	Sections	...
700	Polyester general purpose	Solution	...	Powd.-liq. mortar	Fiberglass reinforced	Sections	Vessels, hoods
500	Phenolic resin	Solution	...	Powd.-liq. mortar	Asbestos filled	Sections	Vessels, towers
600	Epoxy resin	Solution	...	Powd.-liq. mortar	Fiberglass reinforced	Sections	Vessels, pumps
550	Furan resin	...	...	Powd.-liq. mortar	Asbestos filled	Sections	Vessels, towers
	Silicate cement	...	...	Powd.-liq. mortar			

Structural Plastics–

(Continued From Page 138)

wrapped around the tank. After eight months, there are no observable leaks.

Case 10. A brick floor with Portland cement joints failed when subjected to dyehouse wastes. All open joints were pointed with an epoxy cement. The entire floor was given two coats of an epoxy based protective coating. No further difficulty was noted after four months' service.

Case 11. A glass pipe line subject to occasional breakage was wrapped with glass cloth impregnated with catalyzed epoxy resin. The armored pipe has not broken in spite of occasional impact during a six-month period.

Case 12. A solvent welded schedule 40 Type I PVC pipe which had burst due to occasional pressure surges was wrapped with wire mesh and covered with polyethylene tape. No leaks have been noted in a two months' period.

Case 13. Inexpensive ductwork carrying hot nitric acid fumes was constructed by cementing calendered Type I PVC sheet to form a 15-inch tube. An epoxy cement was trowelled over the duct in place and wire mesh was wrapped around it while the cement was soft. A second coat of cement was applied and the entire composite structure was wrapped with polyethylene tape.

Case 14. A swimming pool was constructed with a Portland cement shell which was coated with catalyzed liquid Thiokol. An inner shell of concrete was applied by high pressure spraying. The pool is liquid tight after three months.

Case 15. A serviceable acid resistant floor was constructed as follows: After the application of a ¼-inch plasticized asphalt membrane, a 2-inch layer of silicate cement was spread over the membrane. Brick was imbedded in the fresh silicate cement which was allowed to exude to within ¾-inch of the top surface. Two days later the joints were painted with an epoxy cement.

Case 16. An etching solution consisting of a mixture of nitric, hydrochloric and phosphoric acids with traces of hydrofluoric acid at 160 F destroyed a special alloy tank in less than one week. Attempts to use wooden tanks were also unsuccessful although they lasted three weeks.

Tests showed Type I PVC to be the only satisfactory material. Attempts to use a composite unplasticized-plasticized PVC laminate were also disappointing since the solution permeated the thin rigid PVC layer.

The final structure consisted of a Type I PVC liner inserted within a steel tank protected by a chlorosulfonated polyethylene coating. Sheet foam rubber was placed between the two linings to allow for differential expansion. Since the installation has been in service for three months only, it is too early to determine whether or not the structure is completely successful. The construction does demonstrate creativity with plastics in corrosion engineering in an environment where all other materials proved inadequate.

Conclusion

The examples cited demonstrate the intrinsic versatility of these materials of construction. Engineers who have recognized the shortcomings and advantages of plastics will continue, of course, to make use of all previously available information. It is hoped that they and others who are less familiar with plastics will use these materials to solve more problems through the intelligent application of plastics as materials of construction.

As more engineers become cognizant of the versatility of the many available plastics, many problems that now plague the chemical industry will cease to exist.

Much of the information and the conclusions outlined in this report are the result of surveys and studies by NACE Committee T-5D on Plastic Materials of Construction. Efforts of the members of that committee and the many engineers who have cooperated with this committee are gratefully acknowledged.

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TABLE 2—Relative Resistance[1]

NACE No.[2]	Material	RELATIVE RESISTANCE							RELATIVE		
		Temp.	Weather	Solvents	Salts	Alkalis	Acids	Water	Cost	Strength	Ductility
	Sulfur	5	9	2	10	1	8	10	10	2	2
100.1	Polyethylene, low density	2	7	5	10	10	9	10	7	3	10
100.2	Polyethylene, high density	4	7	5	10	10	9	10	7	4	6
	Asphalt	1	7	1	10	7	6	10	10	1	3
	Coal tar pitch	1	7	1	10	10	6	10	10	1	3
	Coumarone-indene resin	1	7	1	10	10	6	10	10	1	4
	Styrene rubber blend	3	6	3	10	8	6	10	7	6	6
1.0	Polymethyl methacrylate	3	7	4	10	7	6	10	4	6	7
205.1	Polyvinyl chloride, plasticized	3	7	4	10	9	8	10	6	4	10
205.0	Polyvinyl chloride Rigid Type I	3	7	6	10	10	9	10	5	7	4
	Polyvinyl chloride Rigid Type II	3	7	5	10	10	8	10	5	6	8
206.0	Vinyl chloride acetate copolymer	3	7	3	10	7	7	10	6	4	6
200.0	Polyvinyl acetate	1	6	2	10	3	2	9	8	2	4
250	Saran	3	7	5	10	7	8	10	5	7	7
300	Polytetrafluoroethylene	9	10	10	10	10	10	10	1	2	6
800	Silicone	9	9	3	10	4	3	10	1	3	7
50	Nylon 6, 6	6	7	7	10	7	2	10	3	10	7
650	Polyurethane	4	7	5	10	5	2	10	2	0	7
	Natural rubber	4	6	2	10	10	6	10	7	4	10
	Chlorinated rubber	3	6	2	10	10	7	10	6	3	3
102	Chlorosulfonated Polyethylene	4	6	3	10	10	8	10	3	4	10
	Neoprene	4	7	3	10	10	6	10	6	4	10
150	Polysulfide rubber	2	7	8	10	3	3	10	3	3	10
70.1	Cellulose Acetate	3	6	3	10	2	2	9	6	4	7
700	Polyester, general purpose	6	7	6	10	3	4	10	6	6	7
500	Phenolic resin	8	8	9	10	3	7	10	8	5	6
600	Epoxy resin	8	8	6	10	7	6	10	6	5	7
550	Furan resin	8	6	10	10	10	6	10	8	5	6
	Silicate Cement	10	3	10	9	1	9	4	10	2	2

1. Ratings are from 1-10 with 10 being the most desirable. Values are qualitative and can be varied somewhat by special compounding techniques. For example, the irradiation of polyethylene increases the resistance to heat and decreases ductility while the addition of Thiokol o epoxy resin increases ductility and decreases the resistance to heat.

2. NACE numbers are tentative and much work remains to be done before the system is acceptable. It is believed, however, that the use of the numbering system will stimulate suggestions which will aid T5 D in its undertaking.

CORROSION ABSTRACTS

INDEX TO CORROSION ABSTRACTS

Vol. 13 June, 1957 No. 6

1. GENERAL

1.2 Importance

1.2.2, 8.9.5
Some Considerations in the Economics of Tanker Corrosion. A Contribution to the Work of NACE Technical Committee T-3H on Tanker Corrosion. C. P. DILLON. *Corrosion,* **12,** No. 9, 67-69 (1956) Sept.
A concept is presented whereby the capitalized cost of deferred repairs is considered when economic justification of corrosion control measures on oil tankers is contemplated. The author suggests a means whereby data pertaining to tankers can be used in establishing justification for or causing abandonment of corrosion control schemes.
When capitalized cost is considered, the savings attributable to corrosion mitigation measures are much less than when calculated without taking into account earned interest on accumulated repair funds. Formulae are presented and a suggested graphical presentation of the data is included. 12123

1.7 Organized Studies of Corrosion

1.7.1, 2.2.2, 6.4.1
Atmospheric Corrosion Stations of the ISML (In Italian.) G. LUFT. *Alluminio,* **25,** No. 7/8, 321-332 (1956) July-August.
Installation at Arenzano and Novara, results on the behavior of rolled light alloys exposed to industrial, urban and marine atmospheres.—MR. 12484

1.7.3
The Training of Corrosion Specialists, Electroplaters and Materials Specialists in Germany. (In German.) W. MACHU. *Werkstoffe u. Korrosion, 7,* No. 1, 6-8 (1956) Jan.
A comparison, particularly as regards corrosion, of the position in UK, USA and Germany.—BNF. 12410

1.7.3, 5.2.1
Training—the Key to an Effective Cathodic Protection System. T. R. STILLEY AND W. H. HOBBS. *Gas,* **32,** No. 3, 54-57 (1956) March.
Report shows how a complete corrosion control program for a gas distribution company can be initiated in a short time with minimum of experienced corrosion engineering personnel. All personnel connected with gas operations were included in an initial training program. Outline of program included: basis of corrosion and its prevention—mechanism and methods of control; coatings—objectives of pipeline coating, properties, types and applications; cathodic protection—galvanic cell action, coatings in relation to cathodic protection, galvanic anodes, rectifiers, testing, preparation of cables and pipes and operation of system; and discussion of construction practices. Corrosion manual was prepared.—INCO. 12163

1.7.3, 5.2.1, 8.4.2
A Survey of the Personnel and Administrative Side of Corrosion Control. *Gas,* **32,** No. 3, 49-53 (1956) March.
Nationwide survey into organizational and policy matters concerning corrosion control in gas distribution and transmission companies. People required and their qualifications, over-all costs, equipment used, and administration are covered. Graphs and tables show percentage of companies employing full-time corrosion engineers and assistant staff, extent of responsibility delegated to corrosion engineer, responsibilities of corrosion prevention sections and factors determining application of cathodic protection.—INCO. 12025

2. TESTING

2.2 On Location Tests

2.2.1, 2.4.2
The Corrosion Test Spool. R. LAW. *Can. Chem. Processing,* **40,** No. 7, 36-38, 40 (1956) July.
Discusses the corrosion test spool developed at International Nickel Company as means for determining corrosion resistance of metals under actual operating conditions in chemical process plant or pilot plant. Spool holding disk specimens and modified spool-type specimen holder for testing inside pipes are described. Techniques in using test spools, support of specimen holder and examination of specimens after testing are covered. Photographs.—INCO. 12473

2.2.1, 2.4.2
Practical Corrosion Engineering Pays With the NDHA Tester. L. F. COLLINS. Water Doctor Labs. *Heating, Piping, Air Conditioning,* **28,** No. 5, 128-130 (1956) May.
Results of eight years' experience with the National District Heating Assoc.'s corrosion tester as reported by typical users in heating plants, air conditioning systems and industrial processes. Corrosion tester is comprised of helical wire coils electrically insulated from each other and the supporting frame. Corrosion tester as a diagnostic tool can be manipulated without special skills, gives reliable results in a short time, makes its measurements under actual operating conditions, checks its own findings and is not expensive to employ.—INCO. 11963

2.2.2, 6.4.2
Experiences Gained from the Behavior of the Aluminum Roofing of the S. Maria Della Spina Church at Pisa. (In Italian.) G. C. NUTI. *Alluminio,* **25,** No. 3, 135-137 (1956) March.
It is recalled that in 1948 part of the lead roofing of the Santa Maria della Spina church at Pisa, damaged during the war, was replaced by 99.534% sheet aluminum. To obtain a protective coating of suitable color the MBV process was applied with 3 to 4 minutes of immersion at 90-100 C followed by a sealing in 15% sodium silicate solution at 90 C for 15 minutes. After 7 years of service a sample taken from the roofing was subjected to chemical analysis and metallographic examination. The results of these tests and also the protective capacity of the oxide coating, which has been investigated by resistometer, indicate that the method applied provides a durable, technically and aesthetically suitable roofing.—ALL. 12539

2.3 Laboratory Methods and Tests

2.3.1
Methods of Studying Corrosion Indicators. (In Russian.) I. T. DEEV AND K. M. MOROZOVA. *Elektricheskie Stantsii,* **26,** No. 2, 12-14 (1955) Feb.
Use of indicator discs and the metal-

lomiscroscope micrometer. Corrosion product revealed by X-ray. Table, micrographs, photograph.—BTR. 11796

2.3.2, 2.5

Survey of Processes and Specifications for Accelerated Weathering Tests. (In German.) A. Kutzelnigg. *Werkstoffe u. Korrosion,* **7,** No. 2, 65-82 (1956) Feb.

An exhaustive survey based on numerous specifications and other publications from various countries. The information is set out in tabular form and covers all types of material, metallic and non-metallic (largely the latter), and numerous variations of conditions of test.—BNF. 12056

2.3.4, 2.4.2

The Design and Performance of Small Climbing Film Evaporators. D. Pepper. Gt. Brit. Atomic Energy Research Establishment, Harwell, Berks, England, April, 1956, 33 pp.

A review of available design data for climbing film evaporators is presented. Sufficient data are given to enable small-diameter evaporators to be designed for the evaporation of aqueous or similar liquids. The measurement of entrainment and corrosion rates in small climbing film evaporators is described. It is shown that entrainment is worse than in pot-type evaporators but that it can be reduced to an acceptable level by a suitable entrainment separator. The corrosion rate in the evaporator is no higher than that obtained in static corrosion tests on the same materials. (auth)—NSA. 12527

2.3.5, 2.4.2, 4.2.1

Apparatus for Determining the Corrosive Aggressiveness of the Atmosphere. (In Russian.) N. D. Tomashov, G. K. Berukshits and A. A. Lokotilov. *Zavodskaia Laboratoriia* (Factory Laboratory), **22,** No. 3, 345-349 (1956) March.

Principles and use of this apparatus, consisting of a package of copper cathodic electrodes and iron anodic electrodes. Relation of current variation to relative humidity and time. Diagrams, graphs. 9 references.—BTR. 12132

2.3.5, 6.2.3, 8.5.3, 3.8.2

Corrosion Studies of Carbon Steel in Alkaline Pulping Liquors by the Potential-Time and Polarization Curve Methods. Part I. Theory, Methods, and Selected Results. W. A. Mueller. Paper before Corrosion Symp., sponsored by Nat'l. Res. Council, Chemical Inst. of Canada, and NACE, Montreal, September 15, 1955. *Can. J. Technol.,* **34,** No. 3, 162-181 (1956) May.

Potential-time curves and corrosion rates indicate that carbon steel immersed in strong white liquor (100 gm/l sodium hydroxide +35 gm/l sodium monosulfide) displays two stable states which differ in potential and corrosion rate. Chemical or electrochemical pretreatment of steel samples controls range of initial potential and establishment of active state at —1.05 to —1.1 volt, or passive state at —0.65 to —0.8 volt against calomel electrode. Theoretical principles are derived for measurement of reproducible polarization curves and analysis of electrochemical reactions involved. Experimental method for recording continuous polarization curves showed that potentials during conversion from active to passive state form an S-shaped curve. Multipoint curve method measuring corrosion rate and current density as function of potential was demonstrated visually by formation of dark brown film which shifts downward from corroding steel sample. Narrow potential range of high corrosion rate, limited by corrosion-free ranges of anodic or cathodic protection, is indicated. Table, graphs, diagrams.—INCO. 12125

2.3.5, 4.4.6

An Electrical Resistance Technique for Measuring the Corrosivity of Naphtha Streams. W. L. Terrell and W. L. Lewis. *Corrosion,* **12,** No. 10, 491t-494t (1956) Oct.

An accelerated laboratory corrosion test designed to measure the relative corrosivity of naphtha streams was developed by combing and modifying two known methods of corrosion testing. The test was developed because of the need for a rapid, highly sensitive means of measuring some relatively low corrosion rates being experienced in certain naphtha handling facilities. Test spool methods had not proved completely satisfactory for the precise analysis required.

The amount of corrosion was evaluated by measuring the change in electrical resistance of a carbon steel specimen (.001-inch shim stock) during exposure to the corrosive medium. Corrosion losses could be detected to a fraction of a microinch at any time during a test using the apparatus described without

interrupting the test or using any special measuring devices or techniques. Measurable and reproducible corrosion losses were obtained in a test of six hours duration.

It was found that there was good correlation between results obtained with the resistivity test and with retractable coupons. Metal loss measurements made on retractable coupons showed catalytic naphtha to be 60 percent as corrosive as virgin naphtha whereas the electrical resistance tests showed it to be 58.2 percent as corrosive. A comparison of field and laboratory data on evaluation of an inhibitor gave comparable agreement. The electrical resistance technique thus far has been applied only to naphtha and distillate drum water drawoff streams but its use has been investigated and appears promising for other refinery streams. 12341

2.3.6, 2.3.4

New Method for the Direct Microscopic Observation of Electrolytic and Corrosion Processes. (In Hungarian.) ERIK FUCHS AND TIBOR BAUMANN. *Kohaszati Lapok* (Hungarian J. Metallurgy), **11**, No. 3, 107-112 (1956) March.

Application of "Reichert MeF" microscope in combination with test vessels. Diagrams, photographs, micrographs. 4 references.—BTR. 12454

2.3.7, 2.3.4

Stress-Corrosion Cracking Test: Topic of the Month. A. W. DANA AND W. B. DELONG. *Corrosion*, **12**, No. 7, 309t-310t (1956) July.

Experimental apparatus and procedure for studying effect of thermal insulation on cracking of austenitic stainless steel equipment. Photographs.—BTR. 12400

2.3.7, 5.3.2

Electrochemical Investigation of the Corrosion Resistance of Tin Coatings. (In Hungarian.) MIHALY SOLTI, LASZLO KISS AND ANTAL VIGH. *Magyar Kemiai Folyoirat* (Hungarian J. Chem.), **62**, No. 4, 130-135 (1956) April.

An electrographic method using fixed photographic paper was developed to determine porosity of tin coatings, to predict corrosion resistance. Tin plate corrodes in sodium chloride and acetic acid solutions. Diagram, graphs, photographs. 8 references.—BTR. 12598

2.3.7, 2.3.5, 5.4.5

Application of Salt Crock and Soil Stress Tests in Evaluation of Protective Coatings. P. W. LEWIS. *Gas*, **32**, No. 3, 58-59 (1956) March.

Describes salt crock and soil stress tests used to compare coating materials and wraps for protection of buried steel pipe. Salt crock test determines resistance of coatings to current flow and thus helps to establish corrosion prevention properties. Soil stress test exposes coating to severe disruption action of clay during dry-out shrinkage and gives strong indication of its behavior under actual conditions. Indentation test is used to evaluate resistance to puncturing by rocks in backfill.—INCO. 12061

2.3.7, 3.5.8, 3.5.9

Thermal Fatigue Testing of Sheet Metal. H. E. LARDGE. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Symp. on Metallic Materials for Service Above 1600°F., Atlantic City, June 30, 1955. ASTM Special Technical Publication No. 174, 1956, 146-159; disc., 160-163.

Reviews thermal fatigue testing of sheet metal carried out over a number of years. Test program was initiated when cracks were found at edges of holes in sheet-metal flame tubes. Thermal fatigue test was devised based on heating specimen with central hole to 1650 F and then cooling rapidly with blast of air. Thermal cycle was based on temperature curve taken on flame tube on an engine during accelerating and decelerating conditions. Tests on Nimonic 75 showed relationship between increasing sheet thickness and thermal fatigue life, and temperature-life relationship. Data are presented for Nimonics 75, 80A and 90, Inconel, austenitic stainless steels (18-8, 25-16, 20-10), high-chromium ferritic stainless steel, mild and low alloy steels (protected from corrosion by aluminum, chromium coatings and nickel plate) and laminated materials such as Nimoply (copper sandwiched between Nimonic sheets). Tables, graphs, photomicrographs.—INCO. 12055

2.3.7, 3.5.9

Thermal Shock Testing of High-Temperature Metallic Materials. T. A. HUNTER. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Symp. on Metallic Materials for Service Above 1600°F., Atlantic City, June 30, 1955. ASTM Special Technical Publication No. 174, 1956, 164-179; disc., 180-182.

Evaluation of resistance to thermal shock begins with preliminary analysis of thermal-shock damage carried out on theoretical basis. Experimental program was set up and 15 materials selected. Apparatus, specimen preparation, test procedure, and crack definition are discussed. Materials included Types 304, 310 and 347, cermets K151A and K152B, N-155, cast and wrought S-816, Waspalloy, Hastelloy C, Inconel, Nimonic 80A M-252, cast HS-21 and Battelloy (70

chromium-30 iron). Comparative evaluations are made for the various materials at 1600, 1700, 1800, 1900 and 2000 F. Photomicrographs show mechanical fatigue crack and thermal shock crack in Type 304. Tables, bar graphs, diagrams of apparatus.—INCO. 12051

2.3.8, 4.3.4, 8.8.1

Granulation of High-Analysis Fertilizers. L. B. Hein, G. C. Hicks, J. Silverberg and L. F. Seatz. Tennessee Valley Authority. *J. Agric. and Food Chem.*, **4**, No. 4, 318-330 (1956) April.

Description of the development of methods for the production of granular, high-analysis fertilizer. Description and operation of pilot plant includes ammonia and acid stainless steel distributors and stainless steel rotameters used to measure amount of ammonia, nitrogen solution, acid and water feed. Corrosion which occurred on the outside of the distributor was believed to be caused by intermediate products such as hydrochloric acid. Table of corrosion rates of metals in sulfuric and phosphoric acids includes AISI Type 316 and Hastelloy B. A stainless steel acid distributor sheathed in Teflon tubing is being tested and shows promise. Illustrations.—INCO. 12014

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2

What Causes Hydrogen Attack? G. R. King. Humble Oil & Refining Co. *Petroleum Refiner*, **35**, No. 3, 155-159 (1956) March.

Presents briefly the theory of hydrogen attack and describes principal forms of hydrogen deterioration. Formation of blisters, transcrystalline nature of low temperature hydrogen embrittlement, intercrystalline character of high temperature hydrogen embrittlement and accelerators to hydrogen penetration (hydrogen sulfide, cyanide compounds) are discussed. Types of hydrogen attack considered are non-cracked blisters, cracked blisters, fissuring of steel castings, ringworn corrosion, embrittlement and damage to paint. Among remedies and preventive measures suggested are inhibitors, drilling holes in blisters to release internal pressure, lining vessels with gunite or 18-8, chipping or grinding out cracks and welding the areas. Illustrations.—INCO. 12049

3.2.2

Filiform Corrosive Attack on Polished Microspecimens. (In German.) T. Geiger. *Schweiz. Arch. angew. Wiss. u. Tech.*, **22**, No. 1, 16-17 (1956) January.

Filiform corrosion has been found on polished iron and steel microsection. It arises if dust settles on the sections followed by standing in an atmosphere of high relative humidity and necessitates repolishing. It can be prevented by storing in a dessicator.—BNF. 12028

3.2.2

What Hydrogen Does to Metals. H. C. Van Ness. *Petroleum Refiner*, **35**, No. 3, 160-163 (1956) March.

Appraises present state of knowledge of hydrogen embrittlement resulting from presence of hydrogen within metal and of hydrogen attack which is a high-temperature phenomenon caused by formation of methane from hydrogen and carbon in steel; and discusses preventive measures applicable in petroleum and petrochemical industries. Effects of hydrogen embrittlement on the mechanical properties of metals, particularly steels, are considered. Photomicrograph shows decarburization in a low alloy (chromium-molybdenum) steel. Use of liners of resistant materials such as austenitic stainless steel is suggested.—INCO. 12159

3.2.3, 3.7.2, 3.8.4, 6.2.5

Structure of Oxide Scales on Nickel-Chromium Steels. H. J. Yearian, H. E. Boren, Jr. and R. E. Warr. *Corrosion*, **12**, No. 11, 561t-568t (1956) November.

The structure of the scales formed on a series of typical nickel-chromium steels when oxidized for 100 hours in air at temperatures from 1600 F to 2200 F were investigated by X-ray diffraction methods. The scales are of two distinct types. The principal and definitive constituent of the more protective type is chromic oxide. A solid solution of ferric oxide—chromic oxide also may be present; in such cases its ferric oxide content tends to increase with attack rate at any given temperature. For very low attack rates considerable amounts of manganese chromite occur when the alloy contains a few tenths percent of manganese. As the attack rate increases this manganese chromite spinel is replaced by a nickel-chromium-iron spinel, the amount and the alloying element content of which increase with temperature and with the nickel level of the alloy. For an 80 nickel—20 chromium alloy, nickel oxide is also present.

When the attack rate becomes excessive the scale changes to a type containing no chromic oxide phase but consisting of one or more ferric oxide—chromic oxide solutions and nickel-chromium-iron spinels. The ferric-chromic oxide solution tends to concentrate in the outer layer and it then contains less than 10 mole percent chromic oxide; the proportion may increase when it occurs in an inner layer. Spinels are present in all layers but their content of the alloying elements increases in the inward direction.

These results are compared with existing data and interpreted using a theory of selective oxidation and depletion. 12469

3.2.3, 3.7.3

Metallurgical Aspects of Scale Control of Hot Rolled Rods. E. L. Knapp. Paper before Wire Assoc. Midwest Regional Mtg., Kansas City, May 24, 1956. *Wire & Wire Products*, **31**, No. 8, 873-877, 928-929 (1956) August.

Scale layer on surface of hot rolled carbon steels is formed by iron diffusing outwards from the base metal, developing crystalline layers of ferrous oxide, magnetite and hematite. Each of these iron oxides has different chemical and physical characteristics. Surface smoothness of the as-rolled rod can be preserved by rapid cooling to 400 F immediately after finish rolling. Effective scale control can eliminate roughening effect of scale pits on rod surface, sharply reduce steel loss and greatly accelerate rod cleaning production. Graphs.—INCO. 12510

3.2 3, 6.3.6

The Thermal Oxidation and Reduction of a Copper (110) Face. A. Goswami and Y. N. Trehan. *Trans. Faraday Soc.*, **52**, No. 3, 358-361 (1956) March.

An electron diffraction examination of the nature and orientation of the oxide film and of the metal film resulting from reduction.—BNF. 12468

3.2.3, 6.3.11, 7.7

Scaling Phenomena in Sintered Silver Alloys. (In German.) Albert Keil. *Z Metallkunde*, **47**, No. 4, 243-246 (1956) April.

The use of carbides and borides as non-oxidizing components of silver sinter materials for contacts instead of the pure metals molybdenum and tungsten offers no advantages with regard to scaling properties. Graphs, micrographs. 10 references.—BTR. 12488

3.2.3, 6.3.21

Oxidation Characteristics of the Alkali Metals. Pt. I. Oxidation Rate of Sodium Between —79 and 48 C. J. V. Cathcart, L. L. Hall and G. P. Smith. Oak Ridge National Lab. U. S. Atomic Energy Comm. Pubn., ORNL-2054, June 14, 1956, 10 pp. Available from: Office of Technical Services, Washington, D.C.

The oxidation rate of sodium was measured at five temperatures: —79, —20, 25, 35 and 48 C. The reaction rate in dry oxygen was found to be small, and the oxide films were highly protective. A slight increase in the oxidation rate at 48 C occurred after 25,000 to 30,000 minutes of oxidation. No explanation has been found for this phenomenon. (auth)—NSA. 12401

3.2.3, 6.4.2, 3.8.4, 3.7.4

The Oxidation of Aluminium in Dry and Humid Oxygen Atmospheres. R. K. Hart. *Proc. Roy. Soc.*, Ser. A, **236**, No. 1204, 68-88 (1956) July 10.

The oxidation of electrolytically polished aluminum single-crystal surfaces, presenting (100), (110) and (111) faces, has been studied in dry oxygen at 20 C and 760 mm mercury and in 80% saturated oxygen at 25 C and 760 mm mercury; three methods (anodic polarization, electron diffraction and capacity) have been employed to identify and estimate the surface films. Film growth in dry oxygen is at first rapid and then slow, the growth rate being inverse logarithmic ($1/\delta = -K \log_{10}(t + t_0) + K'$). A "practical limit" of approximately 30 Å is reached after several days' exposure. The presence of water vapor increases film growth; after 7 days' exposure aluminum carries films which are about 10 Å thicker than those formed by exposure for the same time to dry oxygen. In humid oxygen, film growth does not cease at a "practical limit" but continues at a slow rate after the initial period of rapid thickening. The growth law is direct logarithmic ($\delta = K \log_{10}(t + t_0) + K'$) during the first 10h of exposure but thereafter inverse logarithmic ($1/\delta = -K \log_{10}(t + t_0) + K'$). The growth of thicker films in humid oxygen is caused by small, though continual, changes in the electrical properties of these films during thickening. The films formed in both dry and humid oxygen were found by electron diffraction to be amorphous. Anisotropy in the growth rate of films on differently oriented metal faces has not been experimentally verified with amorphous films which thicken according to either the direct or inverse logarithmic laws. (auth).—ALL. 12472

3.4 Chemical Effects

3.4.10, 6.3.10

Studies in the Corrosion of Metals Occasioned by Aqueous Solutions of Some

Surface-Active Agents. Pt. V. Nickel. H. Holness and R. D. Langstaff. *J. Applied Chem.*, **6**, No. 4, 140-141 (1956) April.

Action of dilute aqueous solutions of anionic, non-ionic and cationic surface-active agents on 99% nickel foil. One cationic agent, cetyl pyridinium bromide in distilled water, corroded nickel but other cationic and non-ionic agents were almost without effect; nickel was shown to be resistant to attack by anionic agents. —BNF. 12492

3.4.10, 6.4.2

Studies in the Corrosion of Metals Occasioned by Aqueous Solutions of Some Surface-Active Agents. Pt. IV. Aluminium. H. Holness and R. D. Langstaff. *J. Applied Chem.*, **6**, No. 3, 115-124 (1956) March.

Action of dilute aqueous solutions of representative anionic, cationic and nonionic wetting-agents on 99.99% aluminum using London tap-water and distilled water. Attack took the form of pitting, the pits being covered with nodules of corrosion product. All cationic agents had some action on metal; the nonionic agent had little effect.—BNF. 12429

3.5 Physical and Mechanical Effects

3.5.8

On Thermal Aspects of Fatigue. A. M. Freudenthal and J. H. Weiner. *J. Applied Physics*, **27**, No. 1, 44-50 (1956) Jan.

Mainly a mathematical discussion.—BNF. 11992

3.5.8

What You Can Do About Metal Fatigue. Allen G. Gray. *Steel*, **138**, No. 3, 68-72 (1956) January 16.

The increased use of metals nearer the limits of their abilities, in order to save weight and money, has caused an increase in the number of fatigue failures in service. Metal fatigue now accounts for at least four-fifths of the operating failures in machine parts.

Greater mechanization has caused greater emphasis to be placed on the high strength-weight ratio of equipment running at high speeds. Efficient design requires reduction of the size and weight of all parts and this means higher operating stresses.

Precautionary measures can be taken which will greatly reduce the number of fatigue failures in machine parts. More progress against fatigue can be made by examining the fabrication and design operations than by changing to a higher strength metal. Causes and preventive methods given.—RAD. 12030

3.5.8

The Prevention of Fretting Corrosion. R. B. Waterhouse. *Corrosion Prevention and Control*, **3**, 37-39 (1956) March.

This corrosion develops when two surfaces in contact and nominally at rest with respect to each other, experience slight periodic relative movement. 16 references.—BTR. 12150

3.5.8, 3.7.4, 6.3.6

Relationship between Crystal Orientation and Stress-Corrosion Cracking in Alpha and Beta Brasses. H. L. Logan. *J. Research Nat. Bur. Standards*, **56**, No. 3, 159-166 (1956) March.

Crystallographic planes bounding intercrystalline stress corrosion cracks in two large-grained α brasses and those followed by trans-crystalline stress-corrosion cracks in large-grained β brass were determined by X-ray diffraction methods. Intercrystalline stress-corrosion cracking in the α brasses originated between grains that, because of their relative orientation, had high interfacial energy contents. It was concluded that it is relative orientation, not the crystallographic type, that determines the susceptibility to stress-corrosion cracking of α brass in grain boundaries approximately normal to the applied stress. Transcrystalline stress-corrosion cracking of β brass occurred in grains that were oriented most favorably for slip and in planes that were approximately normal to the applied stress. No plane or family of planes in β brass was found to be particularly susceptible to stress-corrosion cracking. It is postulated that in each case cracking progressed by a film rupture mechanism. Illustrations.—INCO. 12067

3.5.8, 6.3.6

The Origin of Fatigue Fracture in Copper. N. Thompson, N. Wadsworth and N. Louat. *Phil. Mag.*, **1**, No. 2, 113-126 (1956) Feb.

Metallographic observations on the development of fatigue cracks in copper (polycrystals and single crystals). Cracks started in slip band inside a single grain. It was confirmed that fatigue life could be increased by preventing access of oxygen to the surface.—BNF. 12148

3.5.8, 8.9.1

Fatigue Aspects of Structural Design. W. A. P. Fisher. *J. Roy. Aeronaut. Soc.*, **60**, No. 543, 198-202 (1956) March.

Deals only with fatigue of wing spar

joints and spar booms with holes, including effect of material advantages of zinc-free aluminum alloys and statistical treatment.—BNF. 12020

3.5.8, 7.2

Here Are Some Answers to Stress-Corrosion Cracking of Your Piping. H. Thielsch. Grinnell Co. Inc. *Paper Trade J.*, **140**, No. 20, 44-46 (1956) May 14.

Discusses stress corrosion cracking and corrosion fatigue in vessels and piping containing acids or caustic and in power plants and steam generating and transmission systems of pulp and paper mills. Causes of static tensile stresses and cyclic stresses are considered. Photomicrographs of stress-corrosion cracks in Type 304 are shown. Effects of steam and water composition are discussed. Most important factor contributing to stress-corrosion cracking is condition of butt welds along inside of piping. Proper joint preparation and welding are reviewed.—INCO. 12158

3.5.9, 4.3.3, 4.2.3

A Simple Phase Equilibrium Approach to the Problem of Oil-Ash Corrosion. W. R. Foster, M. H. Leipold and T. S. Shevlin. *Corrosion*, **12**, No. 11, 539t-548t (1956) November.

Many recent investigations of residual fuel oil-ash corrosion have utilized simulated ashes based upon mixtures of sodium sulfate and vanadium pentoxide. Results of these various studies have not always been easily correlated. It was reasoned that a knowledge of the phase equilibrium relationships in the system sodium oxide-sulfur trioxide-vanadium pentoxide might provide a reliable basis for the comparison and evaluation of such studies. Accordingly, a compatibility diagram was deduced for the system. Volatilization experiments and phase identification by microscopic and x-ray methods confirmed the essential validity of the diagram. When used as a background for the consideration of previous and current oil-ash corrosion research, the diagram was found to be consistent with most of the recorded findings.

It has been found that sodium sulfate and vanadium pentoxide are not compatible with each other in either the crystalline or molten state. They react upon heating with evolution of sulfur trioxide to form sodium metavanadate, as well as several complex vanadates, but not sodium orthovanadate or $Na_4V_2O_7$. The complex vanadates cause the most severe attack of any of the possible corrodents. Vanadium pentoxide, previously credited with a major role in oil-ash attack, emerges as a relatively unimportant corrodent, since vanadium pentoxide as such is absent from all but a few fuel-oil ashes. The only simple sodium vanadate which might function in oil-ash corrosion is sodium metavanadate. There are indications that despite its 74.6 percent content of vanadium pentoxide, its attack is usually mild. Sulfur trioxide which has received little attention in high temperature corrosion studies, has given evidence of potentially severe corrosion. In ashes of high sodium-vanadium ratio, some sodium sulfate persists without decomposition, and in such cases may participate in the attack. 12470

3.5.9, 6.3.10

Oxidation of Nickel-Chromium Alloys at High Temperatures. (In French.) J. Moreau. *Corrosion et Anticorrosion*, **4**, No. 5, 211-216 (1956) June.

Tests to determine if, in a binary alloy, both metals are oxidized simultaneously. Nickel-chromium alloys under atmospheric pressure and between 900 and 1300 C oxidize simultaneously.—BTR. 12532

3.5.9, 1.6, 2.3.7

Symposium on Metallic Materials for Service at Temperatures Above 1600 F (871 C). ASTM Special Tech. Pubn. 174, 1956, 193 pp. Available from: American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

At this symposium (June 30, 1955) after an introduction by V. N. Krivobok, the following papers were read and are reproduced here with discussion:

Some Sheet and Bucket Materials for Jet-Engine Application at 1600 F (871 C) and Higher, J. P. Denny and others (pp. 3-15); Influence of Boron on Cast Cobalt-Base S-816 Alloy, W. E. Blatz and others (pp. 16-23); Effect of Heat Treatment and Structure upon Creep Properties of Nimonic Alloys Between 750 and 950 C, W. Betterridge and R. A. Smith (pp. 29-39); Stress-Rupture Properties of Inconel 700 and Correlation on the Basis of Several Time-Temperature Parameters, S. S. Manson and G. Succop (pp. 40-46); Chromium-Nickel Alloys for High-Temperature Applications, A. G. Bucklin and N. J. Grant (pp. 47-56); Effect of Rare Earth Additions on the High-Temperature Properties of a Cobalt-Base Alloy, J. E. Breen and J. R. Lane (pp. 57-65); Creep, Rupture, and Notch Sensitivity Properties of S-816 Alloy up to 1650 F (899 C) under Fatigue and Static Stress, V. Vitovec and R. N. Lazan (pp. 69-88); Titanium Carbide-Base Cermets for High-Temperature Service, K. Pfaffinger, H. Blumenthal and F. W. Glaser (pp. 90-98); Titanium Carbide Products Produced by the Infiltration Technique, L. P. Skolnick and C. G. Goetzel (pp. 103-109); High-Temperature Properties of Molybdenum-Rich Alloy Compositions Made by Powder Metallurgy Methods, W. L. Bruckart and R. I. Jaffee (pp. 111-134); Tension and Torsion Tests on Nimonic Alloys at High Temperatures, E. D. Ward and W. G. Tallis (pp. 135-145); Thermal Fatigue Testing of Sheet Metal, H. E. Lardge (pp. 146-159); Thermal Shock Testing of High-Temperature Metallic Material, T. A. Hunter (pp. 164-179); The Development of Zirconium-Rich Protective Coatings and Brazing Materials for Heat-Resisting Alloys, A. Blainey (pp. 183-193).—BNF. 11938

3.5.9, 3.8.2, 3.6.6

Effect of the Temperature Factor on the Rate of Corrosion of Metals in Electrolytes. (In Russian.) V. V. Gerasimov, G. V. Akimov and I. L. Rozenfel'd. *Bull. Acad. Sci., URSS* (Izvestiia Akad. Nauk SSSR), Chemical Sciences Section, No. 1, 12-15 (1956) Jan.

Studies of iron-zinc, copper-iron, copper-zinc and copper-magnesium couples in salt solutions or hydrogen peroxide. Graphs, tables. 4 references.—BTR. 11990

3.5.9, 3.8.4, 6.3.10

High Temperature Scaling of Nickel-Manganese Alloys. E. B. Evans, C. A. Phalnikar and W. M. Baldwin, Jr. *J. Electrochem. Soc.*, **103**, 367375 (1956) July.

Scaling rates and scale compositions of nickel-manganese alloys were determined. All the alloys scaled according to the parabolic rate law between 600 and 1000 C. At any given temperature the scaling rate increased at low manganese concentrations, then levelled off at intermediate concentrations, approaching the scaling rate of manganese as the upper limit.

Both an external scale and a subscale were found after scaling, the scale composition being a function of alloy composition and temperature. Above a critical concentration of manganese (15% at 600 C to 60% at 1000 C), the external scale consisted exclusively of manganese oxides; the subscale was MnO. Below this critical concentration, complex external scales consisting of the oxides of both nickel and manganese were found along with subscales of either NiO or a solid solution of the monoxides (MnO + NiO). The spinel oxide ($NiO \cdot Mn_2O_3$) found in most of the complex scales was not associated with improved oxidation resistance. Schematic isothermal sections of the deduced nickel-manganese-oxygen phase diagram were applied as an aid in interpreting the sealing behavior. It is concluded that none of the current theories of scaling of alloys describes the present case. 12031

3.5.9, 4.3.3

High Temperature Reactions of Uranium Dioxide with Various Metal Oxides. S. M. Lang and others. U. S. Nat'l. Bureau of Standards Circular No. 568, February 20, 1956, 32 pp. Available from: Supt. of Documents, Washington 25, D. C.

From experimental data and a survey of the literature (38 references) the high temperature reaction of uranium dioxide with 15 metal oxides is described and many phase-equilibrium diagrams are given.—BNF. 12060

3.5.9, 4.3.3, 2.3.2

Attack of Scaling-Resistant Materials by Vanadium Pentoxide and Effect of Various Alloying Elements Thereon. E. Fitzer and J. Schwab. *Corrosion*, **12**, No. 9, 459t-464t (1956) September.

Investigation into possibilities of developing metallic materials able to stand up under the attack by the combustion gases in crude-oil fired gas turbines is described. Preliminary comparative scaling tests were conducted on metallic copper, nickel, iron and on chromium steels in pure oxygen, vanadium pentoxide-saturated oxygen and in oxygen coupled with intermittent immersion into molten vanadium pentoxide. Vanadium, molybdenum and tungsten were found to be harmful elements. An explanation is given of action of vanadium pentoxide. Other oxides and mixtures of oxides causing accelerated oxidation also are considered.

An account is given of the development of a rapid test which would determine resistance to attack by vanadium pentoxide. Test data are given on numerous steels and alloys known to be scaling resistant. Nature of vanadium pentoxide attack upon iron-base alloys is compared with that for nickel and nickel alloys. Numerical data are given on effect of chromium, nickel and silicon on scaling by vanadium pentoxide. It is concluded that a metallurgical approach can partly solve the corrosion problem involved in vanadium pentoxide scaling. 12127

3.6 Electrochemical Principles

3.6.5, 3.8.2

On the Relationship Between the Natural Electrode Potential and the Corrosion Rate. Rept. III. S. Shimodaira. *J. Japan Inst. Metals*, **20**, No. 2, 93-96 (1956) Feb.

The corrosion reaction of iron in acid solutions has been studied by means of

chemical kinetics. The cathodes of local cells in iron are oxygen electrodes at higher pH than 4 and hydrogen electrodes at lower pH than 4. The corrosion resistivity of metals K is related to the standard electrode potential $E_M°$ and the specific reaction rate constant of hydrogen electrode K_1 by the expression

$$K \equiv \frac{n}{n+\alpha} \log \frac{K_1}{n} - \frac{0.434_{\alpha n}F}{(n+\alpha)RT} E_M°$$

where n is the valence of metal ions, $1 > \alpha > 0$, T the absolute temperature and R and F are universal constants. There seems to be some relation between K and the work function of metals.—JSPS. 12595

3.6.5, 6.3.11

Electrokinetic Potentials on Bulk Metals by Streaming Current Measurements. Pt. II. Gold, Platinum, and Silver in Dilute Aqueous Electrolytes. R. M. Hurd and N. Hackerman. Paper before Electrochem. Soc., San Francisco, April 30-May 3, 1956. *J. Electrochem. Soc.,* **103,** No. 6, 316-319 (1956) June.

Electrokinetic (ζ) potentials of platinum, gold and silver in contact with distilled water were found to be 60.8, 61 and 49 mv, respectively. The ζ potentials were measured as function of concentrations of potassium chloride and potassium hydroxide solutions. Maxima related to solubilities of corresponding chlorides and hydroxides were observed in all cases except that of gold in potassium chloride. Tables summarize all pertinent data while graphs show plots of streaming current vs. pressure drop of metal capillaries.—INCO. 12474

3.6.6

Corrosion and Its Prevention at Bimetallic Contacts. Pamphlet, 1956, 12 pp. Inter-Service Metallurgical Research Council. Available from: H. M. Stationery Office, London, England.

The Council, considering that published information on this subject is inadequate and misleading, arranged for a special panel (headed by U. R. Evans) to compile a suitable guide. The pamphlet begins with a statement of the principles of bimetallic corrosion and its prevention and then provides a table showing the effects of contact between numerous metals and alloys in the presence of water containing an electrolyte. —BNF. 12513

3.7 Metallurgical Effects

3.7.3, 4.4.3

The Performance of Some Soft Solders at Elevated Temperatures and Pressures. H. E. Pattee and R. M. Evans. Paper before Am. Soc. Testing Materials, 59th Annual Meeting, Atlantic City, June 17-22, 1956. Am. Soc. Testing Materials Preprint No. 89d, 1956, 11 pp.

Number of common soft solders (including one containing 91 tin-8 zinc-1 nickel) were tested under cyclic loads of 0-20 psi at 255 F. Solders with high tin content showed longer life under cyclic loading. Additions of 0.2 nickel, manganese, chromium, germanium, tellurium and cerium were added to 30 tin-70 lead and 70 tin-30 lead solders. These additions improved performance of the 70 tin-30 lead solder, but only nickel, germanium and cerium had any beneficial effect on performance of 30 tin-70 lead solder. Zinc, bismuth and antimony improve elevated-temperature properties

when present in low concentrations. Corrosive effects of antifreeze solutions on soldered joints in brass radiators were studied. Tables, diagrams.—INCO. 12549

3.7.3, 5.3.2

Welding of Stainless Clad Steel. K. Ono and K. Watanabe. *J. Japan Welding Soc.*, **25**, No. 1, 12-18 (1956) Jan.; *Library Abs. Bull.*, Tokyo, No. 2, VI-1 (1956) Jan.-June.

Results of the weldability test made on the niobium containing austenitic stainless clad steel (Remanit 1800SS) have clarified the following points. A mild steel electrode of low hydrogen type is best in welding the mild steel side of the plate. The lower layer of the stainless side should first be welded with 25-20 steel electrodes, and then the upper layer be filled with 19 chromium-12 nickel-molybdenum-niobium stainless rods with a similar composition to the clad metal. No appreciable difference was found in corrosion resistivity between the specimens as welded and those after being given cold working such as bending or rolling. Excessive cold working on stainless steel weldments should be avoided because they are easily hardened due to the formation of martensite in addition to the work-hardening. Martensitic structure disappears by annealing at above 1000 C.—INCO. 12547

3.7.3, 6.3.15, 1.6

Arc-Welding Titanium. J. C. Barrett, R. W. Huber and I. R. Lane, Jr. Bureau of Mines, January, 1956, 50 pp.

Arc welds in unalloyed titanium can be made with resulting properties comparable to those of the parent metal, if adequate protection from the atmosphere is provided. Adequate protection usually presupposes that the welding be carried out in a chamber filled with inert gas, although there are occasions when open air welding is fairly successful, provided care is taken to protect the weld by a stream of inert gas issuing from the torch and also, if possible from a trailing shield. The base metal used for welding should have been originally prepared by melting, and it should be homogeneous and of reasonable purity. The weld joint should be so designed that complete penetration can be obtained and the operator (when hand welds are made) should hold the arc for a longer time over one spot than is usual with other metals because of titanium's high melting point. Use of a consumable filler on heavy gages should make higher welding speeds possible. Welded assemblies of titanium have proved successful in tests involving both strength and corrosion resistance. (auth)—NSA. 12423

3.7.3

Jointing of Metals. J. P. Moore. *Metal Ind.*, **87**, No. 14, 277-281 (1955) Sept. 30.

Studies in detail the nature of the surface of the metal and interfacial phenomena such as wetting, diffusion, alloying and melting, the fundamental structural changes occasioned by jointing process which may lead to failure or potential weakness; and corrosion problems associated with metallic joints, as major considerations in soldering, brazing and welding metals.—INCO. 10918

3.7.3, 8.4.5

Some Applications of Welding in the Development of Atomic Energy. L. Rotherham. Paper before Inst. Welding, Liverpool Branch, January 11, 1955. *Brit. Welding J.*, **2**, No. 9, 377-383 (1955) Sept.

Method developed for pressure welding of stainless steel pipe (18 chromium/13 nickel/1 niobium) used in handling highly corrosive and radioactive liquors, is described. Corrosion tests in boiling nitric acid revealed localized zones of attack on outer surface of weld while inside of pipe was not affected in this way and corroded at same rate as rest of pipe. Technique for positional welding of aluminum pipe is described and problem of joining dissimilar aluminum alloys is mentioned. Materials handling the process gas, uranium hexafluoride (Monel, nickel, nickel-plated steel), required welded joints to eliminate dangers associated with flanged joints. Tables, photomacrographs.—INCO. 10969

3.7.3, 8.10.3

Coal Bucket Welds. W. E. Palmer. Champion Rivet Co. *Welding Engr.*, **40**, No. 11, 63 (1955) November.

Both bare and coated nickel-manganese electrodes are used to replace teeth and repair cracks in coal buckets. E7016, new low-alloy high-tensile electrode, replaces stainless electrode for welding cracks in manganese and attaching manganese wear plates and eliminates peening. New, high-speed rod, for use in manganese and carbon steel hardfacing, deposits with the speed of a coated, mild steel iron type rod.—INCO. 10928

3.7.3, 3.5.9, 4.6.2

Bolting Materials for High-Temperature Steam-Plant Service. M. G. Gemmill and J. D. Murray. *Engineering*, **180**, 824-827 (1955) Dec. 16.

Review of recent developments in bolt technology. Properties are given of Durehete 900 and 950 chromium-molybdenum-vanadium steels suitable for long-time bolt service at 950F. Systematic study was made on influence of carbon, molybdenum and vanadium on properties of experimental 1 percent chromium steels. Important role of carbides in governing creep strength is stressed. Adequate creep-resistance at 1050F is exhibited by 1 chromium—1 molybdenum—0.75 vanadium steel. Creep-resistance of bolting materials is more suitably determined by stress-relaxation test than by constant-load creep test.—INCO. 11399

3.7.3, 6.4.2

Effect of Tight Clamping on the Fatigue Strength of Joints. W. A. P. Fisher and W. J. Winkworth. Aeronaut. Research Council Rep. & Memo. No. 2873, February, 1952 (Published 1955), 10 pp. Available from: H. M. Stationery Office, London, England.

It is shown experimentally that tight clamping of joints improves the fatigue strength of aluminum alloys by reducing the stress concentration at the bolt holes.—BNF. 11402

3.8 Miscellaneous Principles

3.8.2

Utilization of Electrolytic Polishing for the Understanding of the Mechanism of Electrolysis. I. Epelboin. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 94-96; disc. 97.

By electrolytic polishing it can be shown that the initial phenomenon of electrolysis is the formation at the electrode of a layer of adsorbed ions. If the current is cut, the anodic diffusion layer persists and the diffusion potential remains constant for several sec.; the anode potential behaves like a contact potential between the surface of the metal and a layer of adsorbed ions. The hydration of the ions can be computed. Electrolytic polishing can be used to study, as a function of temperature, the valency of the metallic ion that passes directly into the electrolytic solution under the action of the electric field; silver and gold dissolve to univalent ions, platinum, nickel, iron, cobalt, tin and lead to bivalent ions; germanium is quadrivalent or bivalent according to temperature; the case of aluminum is complex. cf. Brouillent and Epelboin, *Compt. rend.*, **238**, 2160 (1954).—MA. 11471

3.8.2

Electrochemical Corrosion in Nearly Neutral Liquids. U. R. Evans. *J. Electrochem. Soc.*, **103**, 73-85 (1956) Jan.

Report on years of study of corrosion mechanism. Considers general corrosion, pitting and immunity. Diagrams, graphs, table. 71 references.—BTR. 11344

3.8.2, 1.6

Proceedings of the Sixth Meeting of the International Committee for Electrochemical Thermodynamics and Kinetics, Poitiers, France, 1954. Book, 1955, 567 pp. Butterworths Scientific Publications, London.

Contains 55 papers (in English: parts of the discussions are in French). The section headings are: fundamental principles, nomenclature and definitions; experimental methods; electrochemical behavior of metals and metalloids; applications (corrosion, batteries and accumulators, etc.); special subject of the meeting was polarography.—BNF. 11287

3.8.2, 3.1

Lectures on Electrochemical Corrosion. (In French.) M. Pourbaix. Cebelcor Technical Report No. 30, February, 1956, 42 pp. Centre Belge d'Etude de la Corrosion, 21 Rue des Drapiers, Brussels, Belgium.

These provisional notes on lectures given at the University of Brussels are limited essentially to a report on the result of original work done since 1934 which is concerned with electrochemistry and corrosion reactions of metals. The lectures cover the following points, among others: economical and technical considerations, scientific considerations, chemical and electrochemical reactions, chemical equilibria, electrochemical equilibria, electrochemical kinetics, corrosion and protection of iron and its alloys. Numerous diagrams are included. 11369

3.8.2, 5.8.3, 3.8.4

Adsorption Phenomena and Electrochemical Kinetics. A. N. Frumkin. *Progress of Chemistry, USSR* (Uspekhi Khimii), **24**, No. 8, 933-950 (1955).

Discussion of certain results in the field of investigation of relationships between adsorption phenomena at the metal-solution interface and electrochemical processes. 82 references.—ATS. Translation available: Associated Technical Services, P. O. Box 271, East Orange, New Jersey. 11382

3.8.2, 6.3.2

Equilibrium Potential/pH Diagram for Cadmium at 25C: Corrosion of Cadmium. E. Deltombe and M. Pourbaix. Proc. 6th Meeting Internat. Cttee. Electrochem.

Thermodynamics and Kinetics (Poitiers, 1954), 1955, 133-137.

Calculations are made of the equilibrium between cadmium, cadmium hydroxide, water and the aqueous ions, H^+, Cd^{2+}, and CdO_2H^- at 25C. Cadmium hydroxide has a minimum solubility at pH ~11.1. The passivating film obtained by anodic polarization of cadmium consists of cadmium hydroxide. For pH < 10, cadmium can be protected cathodically by lowering the potential to < -0.6V.; for pH > 10, the potential required decreases and becomes -0.95V. for pH $= 15$. The rate of corrosion of cadmium is compared with that of zinc. 14 references.—MA. 11455

3.8.2, 6.3.4, 5.3.2

Equilibrium Potential/pH Diagram for Cobalt at 25C. E. Deltombe and M. Pourbaix. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 153-166.

From a critical study of published work on the anodic oxidation of cobalt, the standard free energies of formation of Co_3O_4 and CoO_2 are calculated to be $-167{,}835$ and $-51{,}840$ calories, respectively, at 25C. Calculations are made of the equilibria between Co, CoO, $Co(OH)_2$, Co_3O_4, $Co(OH)_3$, CoO_2, water and the aqueous ions, H^+ Co^{2+}, Co^{3+}, and CoO_2H^-. Co^{2+} is oxidized in a very acid medium to Co^{3+} at a potential of $+1.808$ v; CoO_2, which decomposes water to form $Co(OH)_3$ and oxygen, is formed at the time of the anodic oxidation of cobalt in alkaline solution; from MCo^{2+}, $Co(OH)_2$ is precipitated at pH 6.3. In very alkaline solution, cobalt dissolves as CoO_2H^-. With all reactions reversible, electrolytic deposition of cobalt from MCo^{2+} is possible only at pH 4.8—6.3; this applies also in practice, because the hydrogen and cobalt overvoltage are approximately equal; methods of electrolytic production of cobalt are discussed. For electroplating, cobalt has some advantages over nickel, such as less polarization; it is said that, from some solutions, adherent deposits can be produced on copper, brass, iron and steel. 36 references.—MA. 11429

4. CORROSIVE ENVIRONMENTS

4.6 Water and Steam

4.6.2, 5.7.7, 2.3.4

Controlling Iron and Copper Pickup with Neutralizing Amines. J. D. Ristroph and E. A. Yorkgitis. Paper before Am. Soc. Mech. Engrs., Ann. Mtg., N. Y., November 28-December 3, 1954. *Trans. ASME,* **78,** No. 2, 287-294; disc., 294-297 (1956) Feb.

Cyclohexylamine and morpholine were fed continuously to the deaerator outlet of high pressure, reheat, controlled-circulation boiler of a central power station. Steam-feedwater was held close to pH of 9 in the hot-well condensate and after stabilization period, comparative data on iron and copper pickup were obtained. Sampling methods and analytical techniques using improved indicators (bathophenanthroline and neocuproine for iron and copper, respectively) are described. All sampling was done through stainless steel lines with Inconel cooling coils and stainless steel valves. During treatment with either amine, average iron and copper concentrations throughout system were less than 0.01 ppm. Tables, graph.—INCO. 11641

4.7 Molten Metals and Fused Compounds

4.7

Solubility of Iron in Fused Chlorides of Alkali and Alkaline Earth Metals. V. P. Kochergin, M. S. Garpinenko, O. N. Skornyakova and I. Sh. Minulina. *J. Applied Chem., USSR* (Zhur. Priklad. Khim. SSSR), **29,** No. 4, 566-569 (1956).

Above studied in magnesium, potassium, calcium, sodium and barium chlorides. 24 references, 4 figures.—ATS. Translation available: Assoc. Tech. Services, P. O. Box 271, East Orange, New Jersey. 12076

4.7, 3.8.2

Behaviour of Electrodes in Molten Salts. (In French.) Roberto Piontelli, Gunther Sternheim and Maurizio Franzini. *Compt. Rend.,* **242,** No. 10, 1301-1303 (1956) March 5.

The systems investigated were: 1) magnesium (solid)/magnesium chloride (35%)—potassium chloride (47%)—sodium chloride (18%) weight at 550 C; 2) aluminum (solid)/aluminum chloride (70%)—sodium chloride (30%) at 220 C. The apparent overpotential between the operating electrode and a reference electrode, as a function of currnt density, was observed. This overpotential is assumed to be a result of (a RI drop in that layer of the bath where the polarizing current passes and which is also part of the cell formed by the operating and a reference electrode mentioned above; (b) of all eventual contributions from the process of ion exchange between metal and bath. These phenomena of passivity are characterized by conditions of instability and even oscillations, analogous to those observed in aqueous media. —ALL. 12083

4.7, 6.2.2, 5.3.4

The Attack of Iron-Saturated Molten Zinc on Aluminium-Containing Iron. (In German.) D. Horstmann. *Arch. Eisenhuttenw.,* **27,** No. 3, 161-163 (1956) March.

Effects of time and temperature on the corrosive attack of iron-saturated molten zinc on iron containing up to 4.9 aluminum were investigated. Rate of corrosion increased with aluminum contents up to 1%, but with 5% aluminum corrosion is less than in the aluminum-free material. Structure and growth of iron-zinc alloy layers were investigated. —INCO. 12040

4.7, 6.2.2, 5.3.4

Attack of Zinc Melts Saturated with Iron on Iron Containing Manganese. Hans-Joachim Wiester and Dietrich Horstmann. *Arch. Eisenhuttenw.,* **26,** No. 4, 199-204 (1955).

Specimens of iron with various manganese contents were immersed in iron-saturated zinc melts for different periods at different temperatures and the weight loss was determined after the coating of zinc and iron-zinc phases had been pickled off. At manganese contents below 2%, the results were similar to those on iron, i.e. there is a limited temperature range around 500-520 C, of rapid weight loss, linear with time, while corrosion at higher and lower temperatures follows a parabolic law; the effect of increasing manganese content up to ~2% is to narrow the critical temperature range until linear attack is completely suppressed. At manganese contents greater than ~5.5%, linear corrosion reappears, and an alloy with 9.3% manganese suffered rapid attack, linear with time, at all temperatures between 430 and 540 C. Where corrosion is parabolic, the rate of attack increases gradually with rising manganese content. Accelerated, linear corrosion is attributed to the absence of a continuous layer of the ζ phase. Evidently low manganese contents facilitate the formation of this phase and thus reduce the incidence of linear corrosion; on the other hand, manganese increases the rate of diffusion through the alloy layers and thus accelerates parabolic attack. When the manganese content is so high that even slow cooling produces intermediate or martensitic structures the high level of internal microstresses leads to such rapid diffusion that the ζ phase again forms separate crystals which float in the melt and disrupt the formation of discrete layers Alloys with intermediate manganese contents, around 4%, suffer no linear attack and are therefore less sensitive than pure iron to overheating in service as galvanizing tanks, but they are attacked more rapidly at normal temperatures when corrosion is parabolic.—MA. 11940

5. PREVENTIVE MEASURES

5.1 General

5.1, 8.9.3, 1.7.3

What Records Should be Kept to Expedite a Good Corrosion Mitigation Program? M. E. Parker. *Pipe Line Industry,* **2,** No. 1, 53 (1956) Jan.

Records needed for evaluating a corrosive problem comprise complete construction and leak record data on all lines in a system. Suggestions are made for compiling such data in chart form for convincing presentation to management. 11514

5.8 Inhibitors and Passivators

5.8.2

Systematic Investigations of the Anti-Corrosive Action of VPI (Vapour Phase Inhibitor) on a Series of Common Metals. (In German.) W. Paul. *Werkstoffe u. Korrosion,* **7,** No. 4, 189-198 (1956) April.

Tests with moist air on cast iron, steel, copper, brass (62.8/36.4), tin bronze, cadmium, Duralumin (aluminum/copper/magnesium 92.85/4.49/1.66), zinc and silver, using VPI paper (with and without contact). Results described in detail, with color photographs. With VPI in contact copper, brass and bronze show slight tarnishing, cadmium is strongly corroded, other materials unaffected; with VPI in gas phase, only steel is entirely unaffected.—BNF. 12113

5.8.2, 4.3.2, 5.8.3

Inhibition of Iron Dissolution in Acid Solutions. Cecil V. King and Eric Rau. *J. Electrochem. Soc.,* **103,** No. 6, 331-337 (1956) June.

The inhibition of iron dissolution from rotating cylinders has been studied in solutions of dilute hydrochloric or perchloric acid with excess nitrate as depolarizer. No better over-all oxidizing inhibitor than dichromate was found. Complexing and chelating agents greatly improve protection by dichromate in hydrochloric acid although they simultaneously shift the iron potential in the anodic direction. Iron is protected better by dichromate alone in perchloric acid; chelants tend to make the potential more cathodic, but shorten the time of protection.

Neocupferron, which forms insoluble chelate salts with iron ions, protects iron for many hours in these solutions. Carbon monoxide was studied as an adsorption inhibitor. 12045

5.9 Surface Treatment

5.9.4

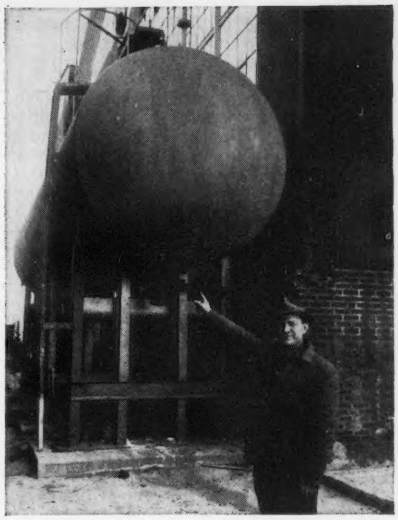
Contribution to Research on the Mechanism of Electrolytic Polishing: New Method of Study of the Electrode Process. (In French.) C. Chalin. *Rev. Gen. Elec.,* **65,** No. 2, 87-117 (1956) Feb.

After an introductory survey the author records investigations on the study of the electrical operation of an electropolishing cell; energy exchanges at the anode and mechanism of polishing; and a new method of study of the electrode process in which the anode capacity is measured by a low frequency A.C. bridge. The 55 references omit any mention of the work of J. Edwards for the Brit. Non-Ferrous Metals Res. Assoc.—BNF. 11946

5.9.4, 2.3.7

Porosity of Anodic Oxide on Aluminum—Comparison of n-Butane and Krypton Sorption. L. A. Cosgrove. *J. Phys. Chem.,* **60,** No. 4, 385-388 (1956) April.

Surface area, pore volume and diameter of porous type of anodic oxide coating applied to aluminum were investigated by sorption techniques with krypton at



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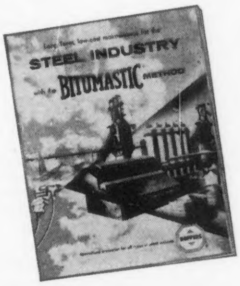

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One of the toughest problems to face the corrosion engineer is protection of steel pickling plants. The dense vapors created by the hot sulfuric acid used can deteriorate the heaviest structural member quickly. Here is a case history of how one company solved this corrosion problem.

* * *

One of the nation's oldest and largest pickling and hot-dip galvanizing firms made a careful study of the problem with the aid of its consulting engineering firm. Past experience has been that little more than eleven years of useful service could be expected from structural members in pickling sheds: the study was undertaken to determine the best protective coating system for new facilities planned.

The first step was to test a wide variety of coating materials under actual service conditions in one of the company's existing installations. The systems tested included expensive multi-coat types, lead-base, synthetics, and coal-tar base coatings. Not only were coatings tested, but various surface preparation and application techniques were compared for economy and effectiveness. Ease of application was of considerable importance since the firm planned to have its own maintenance personnel do the coating job.

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Structural members delivered to the new building site were *completely* cleaned by pickling and neutralizing in the firm's own plant: the importance of thorough surface preparation has also been proven in the test. One coat of Bitumastic Super Service Black was applied by spraying *before* the steel was erected. (Note that the priming step is eliminated with Bitumastic coatings.)

Coating the steel before erection was fast and economical since there was no interference with connecting members. After erection, second and third coatings of Bitumastic Super Service Black were applied to obtain desired system thickness.

* * *

This case history points up the fact that many plant areas previously considered "expendable" can be economically and effectively protected against corrosion. Today, with the high cost of materials and labor, the savings that can be realized by such engineered corrosion-prevention techniques are significant.

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—195.8° and n-butane at 0°. Surface areas are greater for films formed in sulfuric than in chromic or oxalic acid electrolytes. At constant temperature, forming voltage and electrolyte concentration, areas increase with increasing coating time. Areas, calculated for constant coating thickness, decrease with increasing forming voltage and constant electrolyte concentration and temperature. Graphs. —INCO. 11967

5.9.4, 3.4.9, 7.7

Some Electrical Effects of the Absorption of Water Vapour by Anodized Aluminium. A. C. Jason and J. L. Wood. *Proc. Phys. Soc.* (London), Sec. B, **68,** Part 12, No. 432B, 1105-1116 (1955) December 1.

It has been found that at a given temperature the capacity and the leakage resistance of a condenser containing aluminum oxide as the dielectric material were functions of the relative humidity. Further results and a theoretical foundation for the observed effects are presented. The aluminum was anodized using four different electrolytes: 1) ammonium borate, 2) chromic acid, 3) oxalic acid, 4) sulfuric acid. The capacity and resistance measured at 1000 cycles per second of oxide layers prepared in each of these electrolytes were measured in situ in the anodizing bath immediately after formation of the oxide film. The electrolyte served as one conductor and the aluminum sample in the form of a rod as the other. The samples (4 cm. long x 0.158 cm. diameter) were then washed in tap water for a few minutes, rinsed in distilled water for several hours and a porous conductive electrode of 'Aquadag' was deposited on the surfaces. After they had stood over phosphorous pentoxide for 24 hours the capactiy and resistance of each of these samples was again measured. Results show that resistance and capacity of porous anodized aluminum oxide layers are related to the absorption of water on the surface of the pores. The remarkably large variations of the resistance and capacity are due to conduction down the pore side to the large capacity at the pore base.—ALL. 11939

5.9.4, 5.9.2, 1.6, 2.3.9

The Electrolytic and Chemical Polishing of Metals: in Research and Industry. W. J. McG. Tegart. Book, 1956, 129 pp. Pergamon Press Ltd., London.

A concise account of theory and practice. Chapters on mechanism of electropolishing; electrical characteristics in the polishing process; factors influencing polishing conditions; laboratory and research applications, general principles for laboratory methods; use of perchloric acid and other reactive solutions in electropolishing (with particular reference to explosion risks and precautions); metallographic electropolishing (with table giving all details for a large variety of metals and alloys); industrial electropolishing; chemical polishing and its laboratory and industrial applications. Bibliography of over 200 references.—BNF. 12137

5.9.4, 5.9.3

Mechanism of Electrolytic and Mechanical Polishing of Metals, Especially of Nickel. W. Machu and A. Ragheb. *Z. Metallkunde,* **47,** 176-183 (1956) Mar.

Anodic behavior of nickel in electrolytic polishing baths was investigated. Oxide layer forms during polishing. Porosity is dependent on current density. Polishing effect is obtained with minimum porosity, while etching requires higher porosity of covering layer. Levelling off of surface roughness peaks is discussed.—INCO. 12108

5.9.4, 6.4.2

Corrosion Behaviour of Commercial Purity Aluminium as a Function of Surface Roughness and Thickness of the Anodic Oxide Film. (In German.) R. Lattey and H. Neunzig. *Aluminium,* **32,** No. 5, 252-256 (1956) May.

Sheet aluminum specimens of various surface finishes were anodized, sealed and then subjected to the corrosive effect of a 3% sodium chloride and 0.1% hydrogen peroxide solution for 14 days. The findings indicate that very thin anodic films often provide less protection than no anodic coatings at all; the natural oxide film may be of more value than an incomplete anodizing. Thus it is recommended to carry out the anodic treatment at bath temperature less than 20C and also to apply the boehmite after-treatment. Roughness of the surface, as it increases the specific volume of the oxide formed, is detrimental to the resistance of the metal to corrosion.—ALL. 12059

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5, 3.2.2, 2.3.2, 3.7.2

Pitting Corrosion of 18Cr-8Ni Stainless Steel. M. A. Streicher. *J. Electrochem. Soc.,* **103,** No. 7, 375-390 (1956) July.

1. Factors controlling pitting corrosion and laboratory methods used for its study are reviewed. An electrolytically accelerated test was developed for investigation of pit initiation. A controlled direct current was passed through a cell whose anode was the stainless steel specimen and whose electrolyte was the pitting solution. The number of pits formed depended on the current density, the steel specimen (composition and surface treatment) and the solution (composition and temperature).

2. The accelerated electrolytic pitting method described in Part 1 was used to determine the influence of alloying elements added to 18Cr-8Ni stainless steel on pit initiation in sodium chloride and bromine solutions. Reduction in carbon content, increase in nitrogen content of these steels and alloying additions of molybdenum and silicon increased resistance to pit initiation. Grain boundaries, rather than nonmetallic inclusions, were primary sites of pit initiation during simple immersion or in the electrolytically accelerated test. 12139

6.2.5, 3.5.8

Stress-Corrosion Cracking of Stainless Steel. G. Klingel. *Metal Progress,* **69,** No. 4, 77-78 (1956) April.

Surface stress is often present in hardened stainless steel parts even after stress-relieving treatments. Removal of a thin surface layer after heat treatment can prevent stress-corrosion failures. Micrograph, photograps.—BTR. 12058

6.2.5, 3.7.2, 3.7.3

Corrosion Resistance of Some Austenitic Chromium-Nickel Steels of 18/8/Ti Composition. The Effect of Variation in Chemical Composition and Thermal Treatments. E. J. Heeley and A. T. Little. *J. Iron Steel Inst.,* **182,** Pt. 3, 241-255 (1956) March.

Excellent intrinsic resistance to nitric acid corrosion of 18-8-Ti types may be reduced as result of heat treating operations involved in welding. Grooving occurs after heating at 600-750C, and fissuring appears after heating at 1300C. Degree of impairment varies with different steels of same general composition. Influence of titanium and solicon one corrosion of 18-8-Ti steels containing 0.10-0.13 carbon was investigated. Titanium content was found to be most important factor. Steels with carbon content not exceeding 0.06 and an adequate titanium/carbon ratio are almost completely immune from susceptibility to low and high temperature impairment. Tables, graphs, photomicrographs.—INCO. 12011

6.2.5, 3.7.4, 3.2.2

The Morphology of Precipitates in Titanium-Stabilized Stainless Steel. (In Czech.) Vladimir Cihal and Jaroslav Jezek. *Hutnicke Listy,* **11,** No. 3, 151-154 (1956) March.

Studies in connection with intergranular corrosion, after heating at high temperatures, by X-ray and electron-microscope techniques. Tables, micrographs, X-ray diffractogram. 6 references.—BTR. 11978

6.2.5, 3.8.2

Behavior of 18-8 Stainless Steel in 2 Normal Boiling Nitric and Sulfuric Acid Mixtures. P. E. Krystow and M. Balicki. *Corrosion,* **12,** No. 9, 449t-454t (1956) Sept.

The austenitic stainless steels when exposed to a range of boiling 2N sulfuric-nitric acid solutions pass through a passive zone of negligible corrosion, a transition zone of irregular corrosion and two active zones of substantial corrosion. The corrosion rates in the passive and active zones were as anticipated while the rates in the transition zone were entirely unexpected. A plot of the corrosion rates in the transition zone revealed an unusual hump in the curve whose maximum occurred at a critical concentration.

From spectrographic analyses the corrosion rates of iron, chromium and nickel also were determined. A plot of these rates indicated that the hump in the transition zone of the corrosion curve was attributable to excessive corrosion of chromium in this zone. The percentage of the total corrosion attributable to iron was extremely high and above 99% in all the mixed acid solutions. In the transition zone there was an increase of chromium and nickel corrosion with a corresponding decrease of iron corrosion. 12111

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.2, 3.7.2, 3.8.2

Effect of Impurities on the Rate of Solution of Cadmium in Hydrochloric Acid. (In Russian.) Ia. V. Durdin and S. A. Nikolaeva. Vestnik Leningradskogo Universiteta, Seriia Matematiki. *Fiziki i Khimii,* **11,** No. 4, 83-97 (1956) Feb.

Effect of lead, iron, copper etc. as impurities on the rate of corrosion of cadmium. Relation of rate of solution of cadmium to the degree of its purification by means of fractional distillation. Effect of washing surface of cadmium with nitric acid on rate of solution of thrice-distilled cadmium. Electrochemical mechanism of the solution of metals in acids. Tables, graphs, diagram. 15 references.—BTR. 11958

6.3.3, 3.7.4

Physical Evidence of Dislocations in Chromium. M. J. Fraser, D. Caplan and

A. A. BURR. *Acta Metallurgica*, **4**, No. 2, 186-196 (1956) March.

Chromium sheet, thermally etched at 1300 and 1500C in pure hydrogen, was found to exhibit a number of surface structures which are thought to indicate presence of dislocations.—BNF. 12000

6.3.5, 3.5.7, 3.5.9, 3.8.4

High Pressure Oxidation of Niobium. DONALD W. BRIDGES AND W. MARTIN FASSELL, JR. *J. Electrochem. Soc.*, **103**, No. 6, 326-330 (1956) June.

Niobium oxidizes according to the linear rate law from 400-800C (14.7-605 psia O_2). The oxidation rate is extremely pressure sensitive above 550C. Theoretical considerations indicate that an equilibrium adsorption process occurs prior to the rate-determining step. It was necessary to include a term in the rate equation for the interaction between the adsorbed molecules to interpret results above 650C. The interaction energy is influenced by the initial orientation of the metal surface. The activation energy for the oxidation process is approximately 9 to 10 kcal (500-800C). 11947

6.3.6

Copper and Copper Alloys—A Survey of Technical Progress During 1955. E. VOCE. *Metallurgia*, **53**, Nos. 317, 318, 103-107; 143-152 (1956) March, April.

Survey of recent literature covers: copper mines and deposits and techniques in extraction; foundry practice including general foundry techniques, casting methods (continuous, centrifugal, pressure, vacuum), molding techniques (shell, lost wax, carbon dioxide sand), foundry alloys, stresses in castings and quality control; fabrication practice including hot working, cold rolling, wire drawing, cold-press work, tube production and annealing; finishing and plating techniques including mechanical finishing and heat treating, electrolytic and chemical polish-

ing, electrodeposition of copper and copper alloys, electro-tinning of copper wire, electro-forming, and other coating processes (electroless nickel); properties and applications of copper, aluminum bronzes, alloys containing tin, beryllium-copper, chromium-copper and other alloys; corrosion including atmospheric corrosion, stress and dezincification, aqueous corrosion, corrosion in chemical and general engineering, oxidation and scaling and anti-fouling paints; joining copper and copper alloys by gas shielded arc welding, pressure welding and brazing; powder metallurgy including rolling powdered metals, infiltration of porous iron compacts and hot pressing; physical metallurgy covering constitution and structure, diffusion, physical properties, damping capacity, creep, fatigue and shear properties and mechanical deformation; metallographic and chemical analyses; and methods of testing metallographic and chemical analyses; and methods of testing eddy currents, thickness and hardness. 287 references.—INCO. 12122

6.3.6, 3.7.4

The Directionality of Star-Shaped γ-Phase Inclusions in βγ Brasses. (In French.) E. MENCARELLI AND A. R. WEILL. *Compt. Rend.*, **242**, 254-256 (1956) January 9.

The γ precipitates of a β-γ brass were investigated microscopically along a cleavage plane and simple geometric designs were observed, whose crystalline orientation could be easily determined by etch pits (obtained with ammonium persulfate).—BNF. 12116

6.3.6, 4.3.2, 4.3.6

Corrosion of Copper-Gold Alloys by Oxygen-Containing Solutions of Ammonia and Ammonium Salts. J. I. FISHER AND J. HALPERN. *J. Electrochem. Soc.*, **103**, No. 5, 282-286 (1956) May.

Copper-gold alloys, ranging in gold content from zero to 15 at .%, were exposed to stirred aqueous solutions of ammonia and ammonium salts under oxygen partial pressures of up to 6.8 at. Only copper dissolved under these conditions, a gold-rich film being left behind on the surface of the alloy. As the gold content of the alloys was increased, the rate of solution of copper generally fell off and the rate law shifted from linear, usually to parabolic. Alloys containing 15 at.% gold corroded slowly in solutions containing ammonia only, but were passive in the presence of ammonium sulfate. The effect on the kinetics of solution composition, oxygen pressure and temperature are described, and some of the factors which limit the rate of corrosion are discussed. It is concluded that under certain conditions copper oxides are formed which contribute to the film structure and to limiting the corrosion rate. 12007

6.3.6, 4.3.5, 3.5.8, 3.5.9

Fatigue of Copper (at Low Temperatures). H. M. ROSENBERG AND R. D. McCAMMON. *Metal Ind.*, **88**, No. 18, 373-374 (1956) May 4; *Times Rev. Ind.*, **11**, No. 112, 32 (1956) May; *Metallurgia*, **53**, No. 319, 212-213 (1956) May.

Research to establish whether brass bellows could be safely employed for a liquid helium plant showed that resistance to fatigue mounted rapidly as temperature fell. Further research was concentrated on copper to avoid the complications introduced by the alloy structure of brass. Description of test rig and tensile tests on specimens at very low temperatures is given. Difference in fatigue strength of specimens subjected to various stresses in liquid helium is shown in graph. Specimens loaded gradually enable work hardening to take place before fatigue testing proper begins, resulting in greater ultimate strength. Variation of temperature proved to be an effective means of changing the properties of copper without altering the composition or mechanical structure of the specimen in any way. Illustrations. —INCO. 12147

6.3.6, 6.3.3, 3.6.5

On Zero Charge Potentials in Copper and Chromium. (In Russian.) E. A. USKE AND A. I. LEVIN. *Doklady Akad. Nauk SSSR*, **105**, 119-122 (1955) Nov. 1.

The zero charge potentials in various metals and their dependence on the solution content are not yet sufficiently investigated. Special measurements of zero points in various media are of interest. Some preliminary results of measurements of zero potentials in copper and chromium are given. The method correlating the angles formed by boundaries of the bubbles lying on the surface of the metallic solution and the potential of the electrode is used in the investigation.—NSA. 11935

6.3.8, 5.11, 3.7.3

Best Designs for Lead Installations. M. M. HOOVER. *Chem. Eng.*, **63**, Nos. 3, 4, 5, 228, 230, 232, 234; 224, 226, 228, 230; 226, 228, 230 (1956) March, April, May.

Failures of lead installations are traced to improper evaluation of allowable stress and to improper provision for expansion and contraction. Recommended practice for joining lead sheets is explained with accompanying diagrams. Cases considered are wood stave tanks, launders, towers, flues, flues of circular section, sewer manholes, lead-covered floors, lead-pipe and flanges, high velocity coolers, manhole frames for brick flues and insertion of blind flanges to separate flue flanges. Methods for bonding lead to steel with and without use of tin are reviewed. Diagrams. —INCO. 12037

6.3.9, 5.3.2

Oxidation-Resistant Coatings for Molybdenum. J. R. BLANCHARD. *Materials & Methods*, **43**, No. 2, 180, 182, 184 (1956) Feb.

Sprayed, electroplated and hot-dipped coatings, indicating resistance to thermal shock and impact: aluminum-chromium-silicon, nickel-chromium-boron, chromium, nickel, aluminum-12% silicon.—BNF. 11970

6.3.15

Titanium Symposium: A Panel Discussion Held in Philadelphia, October, 1955. *J. Metals* (Trans. AIME), **8**, No. 1, 21-48 (1956) Jan.

Five short papers and the subsequent discussions: opening address (H. H. Kellogg); present status of titanium development (D. J. McPherson); status of titanium fabrication and its use (J. H. Garrett); background for heat treatment of various titanium alloys (P. D. Frost); future use pattern for titanium (B. S. Mesick).—BNF. 12038

6.3.15, 3.2.2

The Effect of Hydrogen on the Mechanical Properties of Titanium and Titanium Alloys and Control of Hydrogen in Titanium and Titanium Alloys. Quarterly Progress Report No. 1. G. A. LENNING, L. W. BERGER, W. M. ALBRECHT, C. B. GRIFFITH, M. W. MALLETT, D. N. WILLIAMS AND R. I. JAFFEE. Battelle Memorial Institute, Contract AF 33 (616)-2813, June 15, 1955, 23 pp.

The possibility that hydrogen embrittlement is associated with moisture-induced stress corrosion was investigated. The results indicated that moisture did not affect either time to failure or ductility in stress-rupture tests. In order to determine the origin of hydrogen embrittlement, microexamination of a number of fractured tensile specimens showing hydrogen embrittlement was made. In all cases the structure was too fine to show the path of fracture. Ti-140A alloy material, which showed hydrogen embrittlement in tensile tests with round specimens, failed to show embrittlement when tested in sheet form with a coarse alpha-beta structure. Alloy-preparation and—testing procedures for the study of the effect of alloy composition on the tendency to hydrogen embrittlement are described. Microstructural conditions and heat treatments to be investigated for the effect of microstructure on the tendency to hydrogen embrittlement are discussed. In the investigation of the removal of hydrogen by vacuum annealing, the study of high-purity titanium has been completed. The diffusion rate of hydrogen in alpha titanium has been determined between 600 and 800 C by outgassing. Below 650C the diffusion rate decreased markedly. The diffusion in beta titanium was also determined at 900 and 1020C by the outgassing method. The effect of hydrogen content on the rate of hydrogen removal between 100 and 600 ppm at 100C was also investigated. The rate of hydrogen removal (fraction removed/fraction remaining) was independent of hydrogen content for the composition range investigated. The presence of an oxide film was shown to retard the rate of hydrogen removal in vacuum annealing. (auth)—NSA. 11942

6.3.19, 3.8.2, 2.3.5

Study of the Rate of Solution and the Potential of Zinc Being Dissolved in Solutions of Hydrochloric and Sulfuric Acids. (In Russian.) K. A. DVORKIN AND IA. V. DURDIN. Vestnik Leningradskogo Universiteta, Seriia Matematiki, *Fiziki i Khimii*, **11**, No. 4, 99-110 (1956) Feb.

Measuring methods. Electrochemical theory of the corrosion of metals, including the theory of local elements. Relation of rate of solution of rolled or cast specimens to temperature, concentration of acid, and other factors. Tables, graphs, diagrams. 37 references.—BTR. 11980

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 3.5.8

Some Metallographic Observations on the Fatigue Failure of Bare and Clad Aluminium-Copper-Magnesium Alloy Sheet. J. J. SEBISTY AND J. O. EDWARDS. *J. Inst. Metals*, **84**, Pt. 8, 291-297 (1956) April.

The distribution of fatigue cracks in clad and bare aluminum-copper-magnesium alloy sheet specimens of various thicknesses was determined by examination of approximate metallographic sections. The specimens were stressed in fully reversed plane bending at 22,000-50,000 lb./sq. in. for various numbers of cycles up to and including fracture. It was found that the form and extent of

crack damage in the clad material was influenced by the thickness of the specimen, the stress and the number of cycles. In some instances, the crack formations were so characteristic that a reasonable estimate of the fatigue history of a specimen could be made by microscopic examination. With the bare material, however, fatigue damage was found to be highly localized, since the first cracks to appear tended to be preferentially propagated to failure without the formation of additional cracks. In this case, microscopic examination was of little value in assessing the fatigue history. Other phenomena associated with fatigue failure were investigated, but these were not found to give so complete a picture of the progress of fatigue as did metallographic examination. (auth.) —ALL. 12131

6.4.2, 3.5.8

Slip During Fatigue of an Age-Hardened Aluminium Alloy. T. Broom and V. N. Whittaker. *Nature,* **177,** 486-487 (1956) Mar. 10.

Examination of an aluminum alloy with 6.6 zinc, 3 magnesium and 1.4 copper aged to peak tensile strength of 38.2 tons/sq. in. has revealed slip bands in specimens fractured in fatigue at room temperature.—BNF. 11956

6.4.2, 3.7.1

Research on Aluminium-Magnesium Alloys. (In French.) A. Saulnier. *Rev. Met.,* **53,** No. 4, 285-297 (1956) April.

In the first part of the experiments reported a high-purity aluminum-7% magnesium alloy (silicon content: 0.01%) was solution heat-treated at 420 C, quenched in 20 C water and subjected to artificial ageing at 200 C for ten days. At the various stages of the process the structural evolution of the metal was repeatedly investigated by electron microscopy, optical micrography, hardness and microhardness measurements, X-ray analysis and corrosion tests. The results of these observations, covering the variations of the mechanical characteristics and the sensitivity and nonsensitivity to intercrystalline corrosion, indicate that right at the beginning of the artificial ageing (1 or 2 hr.) very small elements of Al_3Mg_2 are precipitated at the intergranular joints and also inside the grains and are surrounded by a reoriented matrix depleted of magnesium. As the ageing progresses the precipitates and corresponding depleted zones gradually increase in number and dimensions. The behavior of the aluminum-magnesium alloy under investigation is compared to the structural hardening and recrystallization mechanism of aluminum-4% copper alloys. In the second part of the experiments reported a commercial aluminum-3% magnesium alloy containing 0.14% silicon, was investigated. It is said that alloys of this type, if heat-treated at 400 C, do not show any substantial hardening after 24 hr. of artificial ageing at 165 C. However, if the temperature of heat treatment is raised to 520 C, a considerable improvement in mechanical characteristics follows. The functional dependence of mechanical properties on the temperature of homogeneization seems to be governed by the fact that silicon present in aluminum-magnesium alloys in any proportion tends to combine and form the ionic intermetallic compound Mg_2Si, part of which, depending on temperature, goes into solution and becomes ultimately precipitated during the ageing process. It is also demonstrated that ageing at 200 C for 24 hr. also produced a thin film of Mg_2Si at the grain boundaries which accounts for the increased sensitivity of such alloys to intercrystalline corrosion.—ALL. 12120

6.4.2, 3.8.2

On the Corrosion Mechanism of Supersaturated Solid Solution of Aluminum-Copper Alloys. M. Mikami and K. Hashiura. *J. Japan Inst. Metals,* **20,** No. 1, 49-51 (1956) January.

Refers to an experiment made to investigate corrosion mechanism of supersaturated solution of aluminum-copper alloys, 4.8% copper and 1.9% copper in 10% hydrochloric acid aqueous solution at 30°. Measuring the volume of hydrogen produced in the corrosion process, results were: (I) In the first stage of the corrosion, aluminum and copper dissolved simultaneously from the solid solution: $(Al\text{-}Cu)_{solid\ soln.} + H^+ \rightarrow Al^{+++} + Cu^{++} + H_2$; (II) Cu^{++} was then reduced by the solid solution as follows: $Cu^{++} + (Al\text{-}Cu)_{solid\ soln.} \rightarrow Cu + Al^{+++} + Cu.^{++}$ Repeating these reactions, a metallic copper phase was formed by the precipitated copper atoms on the surface of the solid solution; in the second stage, the corrosion was increased exceedingly by the electrochemical reaction of copper and aluminum-copper solid solution.—JSPS. 12073

6.4.2, 4.6.1

Corrosion Experiments with 2S Aluminum at 200 C. W. E. Ruther. Argonne National Lab. U. S. Atomic Energy Comm. Pubn., ANL-5500, March, 1956, 12 pp. Available from: Office of Technical Services, Washington, D. C.

Aqueous corrosion experiments using 2S aluminum at 200 C showed the following. Lowest corrosion rates were obtained in dilute sulfuric acid at pH near 3. This was also true at 250 and 300 C. The same amount of sulfate ion in neutral solution caused no significant reduction in corrosion. Dichromate ion and dissolved oxygen increased in corrosion rate (neutral pH). Sodium silicate as a solute resulted in higher corrosion rate when the pH was lowered only to 9.4; at pH 3.5 it reduced the corrosion rate significantly. Chloride ion (5 ppm) caused some pitting and increased the corrosion rate slightly. Coupling to more cathodic materials such as graphite and zirconium caused no noticeable effect on the aluminum corrosion in distilled water. (auth)—NSA. 12145

6.4.2, 4.6.1, 3.6.6

Aqueous Corrosion of Aluminum. Part I. Behavior of 1100 Alloy. J. E. Draley and W. E. Ruther. *Corrosion,* **12,** No. 9, 441t-448t (1956) Sept.

Aluminum alloy 1100 corrodes uniformly in nearly pure water at rates which increase with temperature. The reaction is characterized by an initial period of relatively rapid corrosion, followed by a constant lower rate of corrosion. The slope of the linear part of the curve or the "corrosion rate" changes from about 0.02 to 2.5 mg/dm²-day (.01 to 1.3 mil/yr.) from 50 to 200 C. Above 200 C intergranular attack occurs, with resultant more rapid penetration and deterioration of the metal.

The corrosion rate can be reduced by the addition of an acid to the water. The solution pH of minimum corrosive attack on aluminum goes down with increasing temperature. It is of the order of 6.5 at 50 C and 3 at 300 C.

Corrosion in slightly alkaline solutions (pH 8.5) is more rapid than in neutral water at all temperatures. At 100 C the difference shown in stagnant tests is very slight, but increases considerably if the temperature is increased to the order of 200 C. Presumably the effect of solution flow rate would be greater in the case of alkaline water than in neutral water.

At 200 C the addition of dichromate ion increased the rate of corrosion. A small concentration of sodium silicate resulted in a higher corrosion rate at pH 9.4, while at pH 3.5 it reduced the rate significantly. Chloride ion (5 ppm) caused some pitting and increased the corrosion rate slightly.

Electrical coupling to more cathodic materials, such as graphite, zirconium or stainless steel produced no undesirable effects in distilled water at 200 C. At 315 C, the corrosion life of samples was extended by such coupling. 12121

6.4.2, 3.6.6

Galvanic Corrosion of Aluminium. F. PEARLSTEIN. *Metal Finishing,* **54,** No. 4, 52-57 (1956) April.

Corrosion of aluminum in contact with copper is known to be severe, pitting corrosion occurring on anodized aluminum and more even corrosion on bare aluminum; steel, titanium, nickel and stainless steels are also shown to cause considerable attack on aluminum alloy (24S); tin has little effect and cadmium is anodic to 24S aluminum alloy, being sacrificially corroded. Results of salt spray tests on bare or palted steel or copper discs attached to 24S aluminum alloy panels are given. See also Aluminum Development Assoc. Information Bulletin No. 21, Aluminum in Contact with Other Materials.—BNF. 12099

6.4.4

Thorium-Magnesium Sheet Useful for High Temperature Service. A. V. LEVY. *Materials & Methods,* **43,** No. 3, 114-117 (1956) March.

A discussion of alloy HK31 (3% thorium, 0.75% zirconium), claimed to retain high strength and elastic modulus to about 316 C and to have good creep resistance. An evaluation for use in a supersonic ramjet engine for service above 316 C. Fabrication properties, heat treatment, welding, assembly, fatigue behavior, corrosion resistance. Strength over a range of temperatures is compared with aluminum alloy 2024. —BNF. 12110

6.6 Non-Metallic Materials

6.6.6, 2.3.7

Note on Failure of Ceramic Materials at Elevated Temperatures Under Impact Loading. W. D. KINGERY AND J. PAPPIS. *J. Am. Ceram. Soc.,* **39,** No 2, 64-66 (1956) February.

Apparatus for determining impact resistance of ceramics at temperatures up to 1600 C is described. Samples of aluminum oxide were tested for impact resistance up to 1600 C, magnesium oxide up to 1400 C, Pyrex brand glass up to 700 C, soft glass up to 600 C and semivitreous white ware body up to 1200 C.—BL. 12035

6.6.6, 6.7.2

Refractories. Part I-V. O. P. NICHOLSON. *Metal Ind.,* **88,** Nos. 9, 10, 11, 12, 13; 165-167, 189, 192, 209-212, 230, 232, 245-248 (1956) March 2, 9, 16, 23, 30.

I. Covers generally types of materials available with tables of raw materials (metals, alloys, oxides, carbides, sulfides, silicides) and grouping (acid, neutral, basic). II. Analyses and testing. III. Microscopy and X-ray investigation techniques. IV. Solid-phase changes, thermal changes, specific heat, thermal conductivity. V. Equilibrium diagrams of refractory oxides, with examples. 30 references.—BNF. 12072

6.6.8, 3.5.9

Tests Predict Performance of Plastic Pipe at Low Temperatures. J. W. MINTON. Smith & Stone Ltd. *Gas,* **32,** No. 3, 60-62 (1956) March.

In study of low temperature behavior of cellulose acetate butyrate (Tenite II) extruded plastic pipe, impact tests were conducted at +75 to —40 F and burst tests showed increase of pressure at burst as temperature was lowered. Maximum burst was reached at —20 F with an average burst pressure of 1100 psig. Plot of impact vs temperature indicates that impact quality must be carefully controlled when pipe is used below freezing. Metal-to-plastic adapters used have brass threaded ring which compresses a neoprene seal. Considerable variation in impact and burst strength exists in pipe made under various extrusion conditions from same raw material.—INCO. 12071

6.7 Duplex Materials

6.7.2

Cermets. Part I. Fundamental Concepts Related to Microstructure and Physical Properties of Cermet Systems. M. HUMENIK, JR. AND N. M. PARIKH. *J. Am. Ceram. Soc.,* **39,** No. 2, 60-63 (1956) Feb.

Effect of wettability on microstructure in tungsten carbide-metal and titanium carbide-metal systems, wettability of titanium carbide, hardness and impact resistance of nickel-molybdenum-titanium carbide systems.—BNF. 12048

6.7.2

The Oxidation of Carbide-Type High-Temperature Alloys. J. HINNUBER, O. RUDIGER AND W. KINNA. *Arch. Eisenhuttenw.,* **27,** 259-267 (1956) April.

Effect of tungsten, chromium and tantalum-niobium carbide additions on the rate of oxidation and structure of oxide layers of titanium carbide-cobalt alloys heated at 800-1100 C for 75 hr. Crystallographic explanation of results obtained is given.—INCO. 12036

6.7.2

An Oxidation Study of Cobalt-Alumina Mixtures. W. B. CRANDALL AND R. R. WEST. *Bull. Am. Ceram. Soc.,* **35,** No. 2, 66-70 (1956) Feb.

In order to evaluate techniques for rating cermets for high temperature service, authors determine information obtainable from reaction of cobalt in presence of alumina in powdered compact form at elevated temperature, using automatic balance-furnace, differential thermal analysis and X-ray diffraction. —BNF. 11982

6.7.2

Metal and Self-Bonded Silicon Carbide. (Summary Report for) January 11, 1954 to December 29, 1954. R. E. WILSON, L. B. COFFIN AND J. R. TINKELPAUGH. New York State Univ. Coll. of Ceramics. U. S. Wright Air Development Center, Tech. Rept. 54-38 (Pt. 2), January, 1955, 46 pp. Project No. 7350.

A method for the formation of dense self bonded silicon carbide by hot pressing is outlined. The presence of aluminum in small quantities was found essential to the formation of uniformly dense silicon carbide specimens. Modulus of rupture values at various temperatures, hardness, thermal shock, impact strength and electrical properties were determined for self-bonded silicon carbide containing various amounts of aluminum and iron. Modulus of rupture strength was found to increase with temperature, achieving 69,000 psi at 2500 F. Laboratory evaluation of dense silicon carbide as an uncooled rocket material showed its resistance to oxygen-propane flame erosion to be superior to any material tested previously but some cracking occurred. Molybdenum and silicon carbide was hot pressed to form dense specimens having good oxidation resistance and having a modulus of rupture exceeding 70,000 psi at 1800 F. Effects of the partial replacement of titanium carbide by silicon carbide in a sintered titanium carbide-nickel cermet are described. Infiltration of nickel into silicon carbide and titanium carbide-silicon carbide skeletons was studied and found unsatisfactory because of reactions forming silicides.—NSA. 11941

6.7.2

An Investigation of Boride Cermets. J. A. STAVROLAKIS, N. H. BARR AND H. H. RICE. *Bull. Am. Ceram. Soc.,* **35,** No. 2, 47-52 (1956) Feb.

Cermets are defined as including all composites of any inorganic compound intimately bonded, mechanically or chemically, with a metallic constituent. Fabrica-

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tion methods in present investigation; manganese boride-based cermets; calcium boride-based cermets; silicon-boron cermets.—BNF. 12130

6.7.2

Cermets for High-Temperature Service. J. T. Norton. Paper before Am. Soc. Mech. Engrs., Diamond Jubilee Ann. Mtg., Chicago, November 13-18, 1955. *Mech. Eng.*, **78**, No. 4, 319-322 (1956) April.

Properties of cermet composition based on titanium carbide are discussed and compared with boride base, oxide base and NiAl cermets. Titanium carbide cermet shows a significant increase in strength over high-temperature alloy Nimonic 90. In the 1750-1800 F range, metal bonded titanium carbide alloy has good strength properties and a toughness adequate for many applications. In the 1800-2200 F range, cermet materials of adequate strength are being used in short-time applications. They are, however, too brittle to meet even the minimum specifications needed for many practical applications.—INCO. 12107

6.7.2, 6.6.6, 3.4.6

Stability of Hard Compounds Towards Gases. (In German.) H. J. Boosz. *Metall*, **10**, No. 3/4, 130-136 (1956) Feb.

Calculations from the thermodynamic (enthalpy) point of view, up to 1500 C, of the behavior of carbides of silicon, zirconium, tantalum, tungsten and chromium and nitrides of titanium, zirconium, tantalum and chromium towards water vapor, carbon monoxide, carbon dioxide, gaseous hydrochloric acid, oxygen and nitrogen. Calculations based on data from 57 references. The characteristic stability of the materials under these conditions is found to be small. An incidental consequence of this work is that it appears expedient to replace residual nitrogen by hydrogen in a sintering furnace when vacuum-sintering materials containing titanium carbide.—BNF. 11945

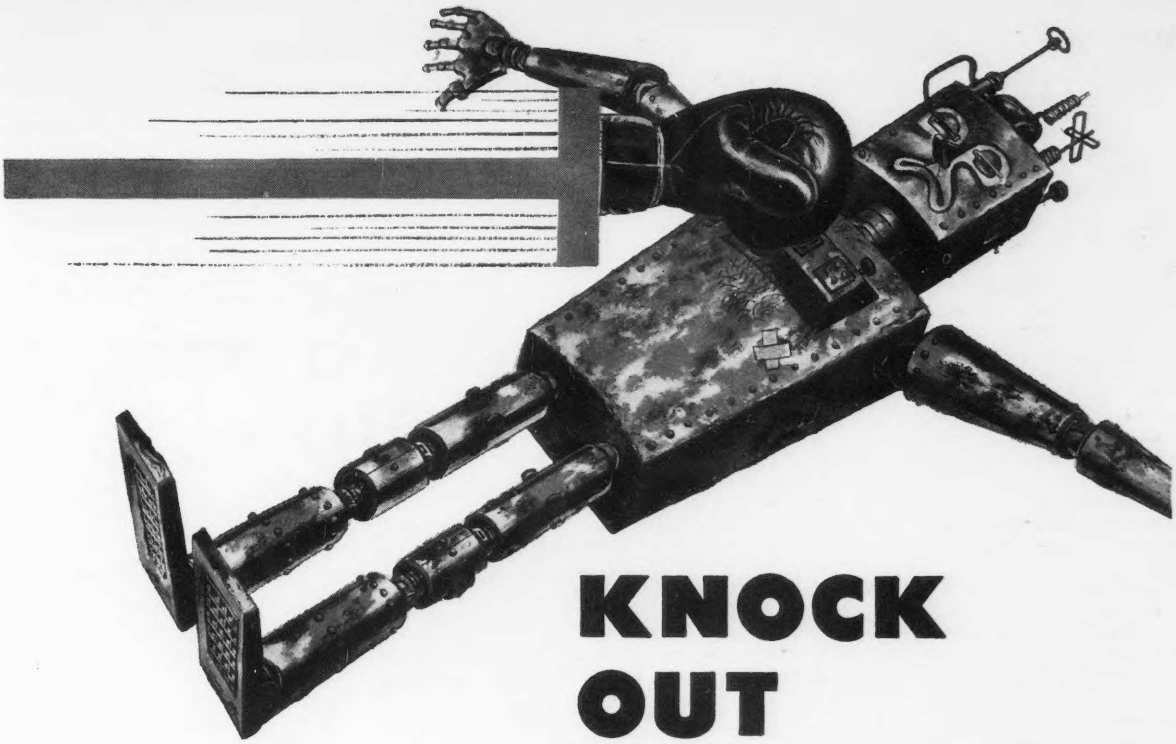
8. INDUSTRIES

8.4 Group 4

8.4.3

Gasoline Plant Corrosion. E. C. Greco. United Gas Corp. *Gas*, **32**, No. 3, 144-146, 148 (1956) March.

Corrosion in gasoline is mainly due to presence of water and carbon dioxide which combine to form carbonic acid. Incidence of corrosion increases with increase in partial pressure of carbon dioxide. Vessels in which corrosion was observed are listed and absorbers and steam stripping mills are described as examples. Cast iron bubble caps in absorbers showed graphitic corrosion. Pits 50-350 mils deep were found in absorber wall behind spill plate. No corrosion was found in absorber when lean absorption oil and rich gas stream were dehydrated before reaching absorber. Good results are reported for injection of organic inhibitor into reflux line. Sodium hydroxide and sodium carbonate treatments are discussed. Methods to determine corrosion and to evaluate control methods are iron determination and Audigage surveys.—INCO. 12019



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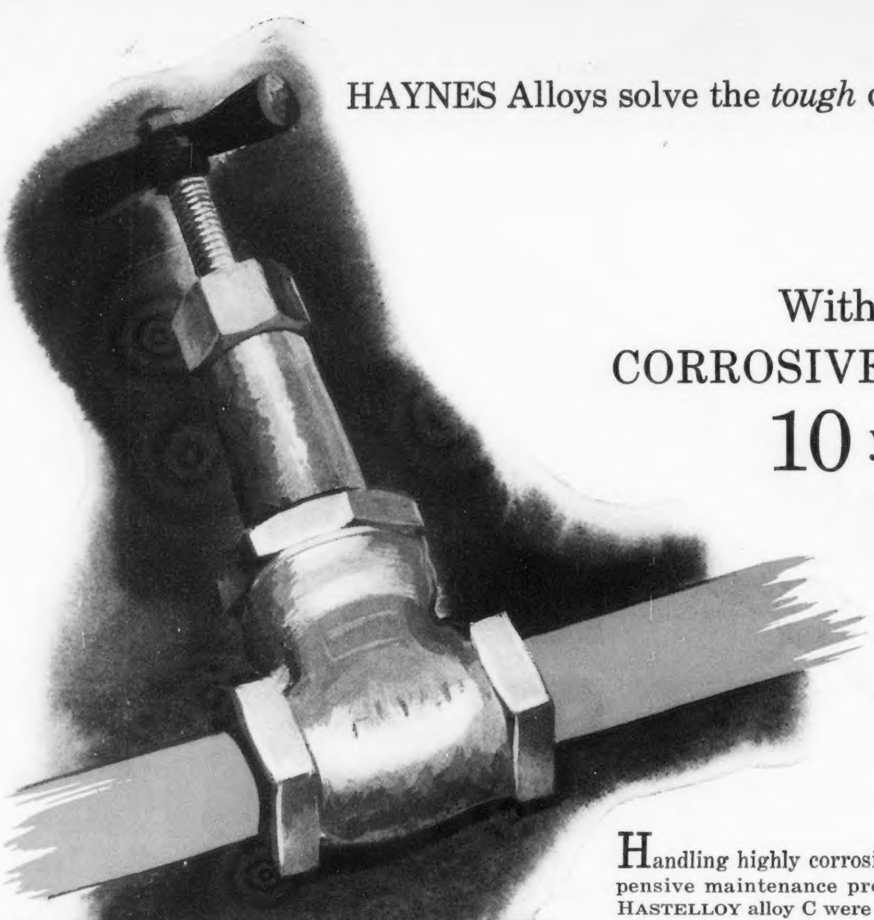

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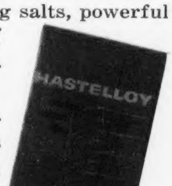

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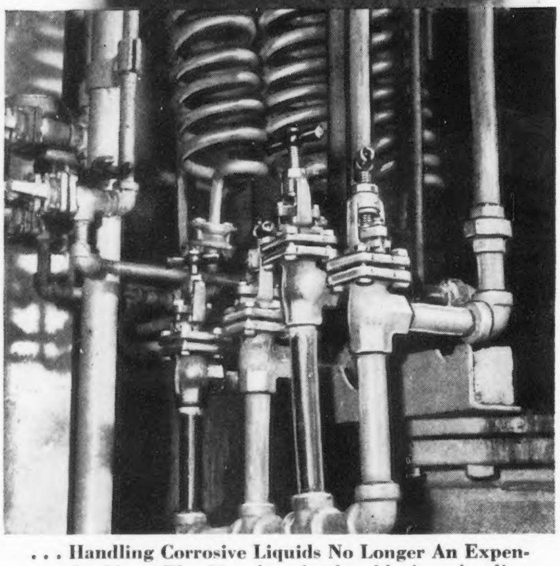

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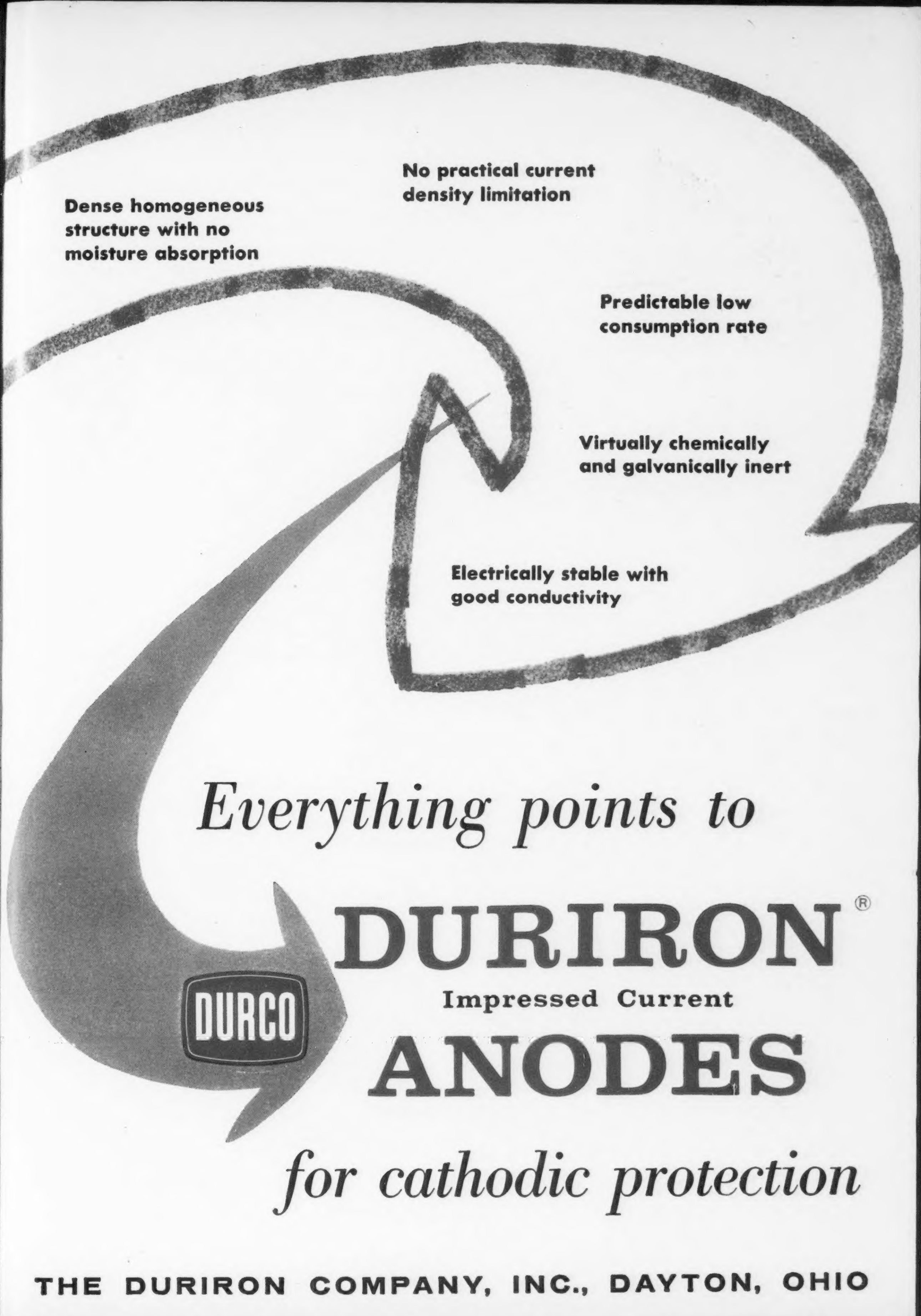

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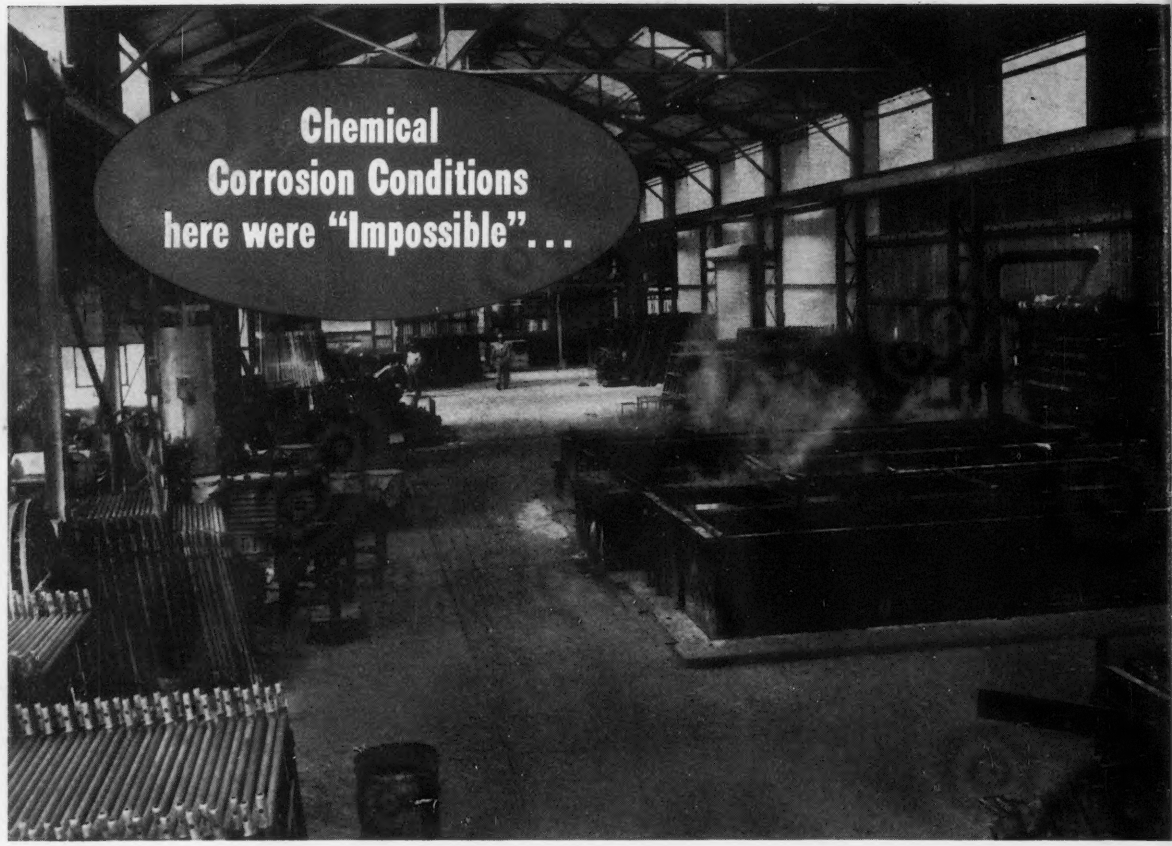

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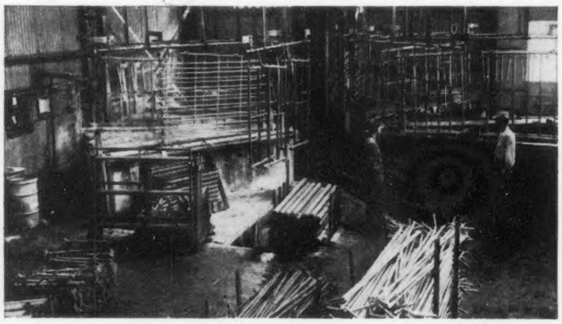

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